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Investigation of a Maritime Hover Manoeuvre in the Air Operations Simulation Centre

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ABSTRACT

This report describes the simulation experiment undertaken in the Air Operations Simulation Centre to assess the viability of a maritime hover manoeuvre in support of a Maritime Addendum to Aeronautical Design Standard 33.

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Executive Summary

As a result of recommendations made by Manso and Arney in DSTO-TN-0936, an experiment was undertaken in the Defence Science and Technology Organisation (DSTO) Air Operations Simulation Centre (AOSC) with the intent of assessing a proposed Aeronautical Design Standard 33 (ADS-33) Maritime Addendum.

The original proposal of a Maritime Hover ADS-33 Mission Task Element (MTE) was heavily altered and subsequently downgraded to a maritime hover manoeuvre in recognition of the fact its assessment of aircraft handling qualities was limited. After consultation with Aircraft Maintenance and Flight Trials Unit the objective of the AOSC trial was revised to assess the viability of a maritime hover manoeuvre and the feasibility of further development toward an ADS-33 MTE; determine a relationship between Usable Cue Environments (UCEs) and sea conditions; and investigate the fidelity of the DSTO simulator as a means for providing UCEs.

To this end, the maritime hover manoeuvre was tested in the AOSC. Several changes were made to the original manoeuvre description. Time on station was reduced from two minutes to 30 seconds, and plan position limits were rates-based rather than position-based. Both these changes were made to reflect the fact the hover was replicating search and rescue operations, in particular that the aircraft would follow the target as it moved in the water, and not attempt to regain the initial position.

The AOSC experiment results were able to identify the limitations of the current simulator for undertaking manoeuvres in low visual cue environments. Although pilot visual cue ratings identified a clear difference between the ground-based and open-ocean environments, the corresponding UCE ratings did not reflect the difference. The subtleties of the differences in the visual cue environments could not be identified by the ADS-33 UCE rating. In effect, these results confirm that the degradation in visual cues between ground-based operations and the open-ocean environment is not easily quantified.

It is the recommendation of this report that neither the Maritime Hover MTE, nor maritime hover manoeuvre be pursued as a viable maritime addendum to ADS-33. Both manoeuvres fail to assess the handling qualities of the rotorcraft; however, there is merit in the potential of the maritime hover manoeuvre to assess the effect of degradation between ground-based and maritime open-ocean operations. Current limitations of the AOSC simulator precluded a full analysis of the maritime hover manoeuvre, and further refinement is required.

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Contents

Acronyms

ADS-33	Aeronautical Design Standard 33 (Handling Qualities Requirements for Military Rotorcraft)
AMAFTU	Aircraft Maintenance And Flight Trials Unit
AOSC	Air Operations Simulation Centre
DGPS	Differential Global Positioning System
DSTO	Defence Science and Technology Organisation
DVR	Diagonal Visual Reference (strategy)
EOS	Experiment Operator Station
HQR	Handling Qualities Rating
MTE	Mission Task Element
NAS	Naval Air Station
PIO	Pilot Induced Oscillation
RAN	Royal Australian Navy
SAR	Search and Rescue
SAS	Stability Augmentation System
SIMDUCE	Simulated Day Useable Cue Environment
UCE	Usable Cue Environment
VCR	Visual Cue Rating

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1. Introduction

As a result of recommendations made by Manso and Arney in DSTO-TN-0936 [1], an experiment was undertaken in the Defence Science and Technology Organisation (DSTO) Air Operations Simulation Centre (AOSC) with the intent of assessing a proposed Aeronautical Design Standard 33 (ADS-33) Maritime Addendum.

ADS-33 (version E [2]), Performance Specification of Handling Qualities Requirements for Military Rotorcraft, is at present the most comprehensive tool available for assessing rotorcraft with respect to mission requirements. Current ADS-33 specifications relate to scout, attack, utility and cargo helicopters by way of Mission Task Elements (MTEs). These MTEs were primarily developed for land-based operations and whilst many mission elements are common between land and maritime operations, ADS-33 does not have provision for maritime-specific MTEs.

This report describes the simulation experiment undertaken by the Royal Australian Navy (RAN) Aircraft Maintenance and Flight Trials Unit (AMAFTU) and DSTO in support of a Maritime Addendum to ADS-33.

2. Background

2.1 ADS-33 Overview

The application of the ADS-33 specification is intended to assure that flight safety and mission capability is not limited as a result of deficiencies in flying qualities of the rotorcraft. To achieve this assessment, the handling qualities criteria and metrics applied are dependent on the helicopter's mission profiles, rather than its role or size.

ADS-33 includes definitions of aircraft response characteristics contingent on the visible cues of the environment, quantitative criteria in both the frequency and time domains, and qualitative criteria based on pilot ratings. Quantitative criteria will not be used in this study.

The qualitative criteria, in the form of characteristic manoeuvres, assure a comprehensive and independent assessment of the handling qualities of the helicopter during certain well defined tasks. These tasks are representative of operational tasks which might occur as part of the helicopter's mission profile. The assessment of a rotorcraft's handling qualities during these particular tasks was made by three pilots, who individually evaluated and rated the handling qualities of the aircraft using the Cooper-Harper scale [3] as per Figure 1.

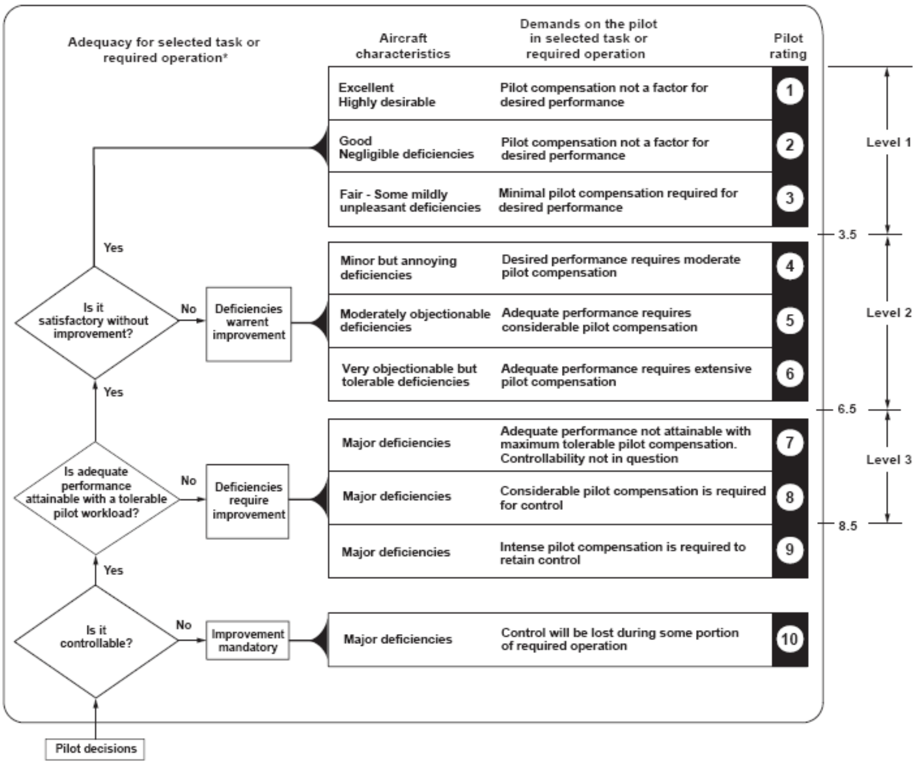

Figure 1 Cooper-Harper handling qualities rating scale [2]

Subjective pilot ratings are given on the Cooper-Harper scale as Handling Qualities Ratings (HQR). For flight within the operational flight envelope, Level 1 handling qualities are required. Level 2 is acceptable in the case of failed and emergency situations, but Level 3 is considered unacceptable. To ensure Level 1 handling, ADS-33 requires that the specifications of the MTE, the Usable Cue Environment (UCE) and the response type are defined.

UCEs relate to the need for different flying qualities in different visual conditions. A UCE of 1 corresponds to very good visual cues that support the aircraft control of attitude and velocity, whereas a UCE of 3 relates to a deficiency in visual cues such that only small and gentle corrections of aircraft flight can be safely achieved.

The response type relates to the short-term aircraft response following a pilot's step control input. Figure 2 shows how the attitude varies for the different response types. An acceleration command relates to a pure conventional helicopter without any stabilisation system. Typically a helicopter will provide rate command stability augmentation, with attitude command and translational command provided by modern control systems. With translational rate command, the piloting is essentially reduced to a steering task.

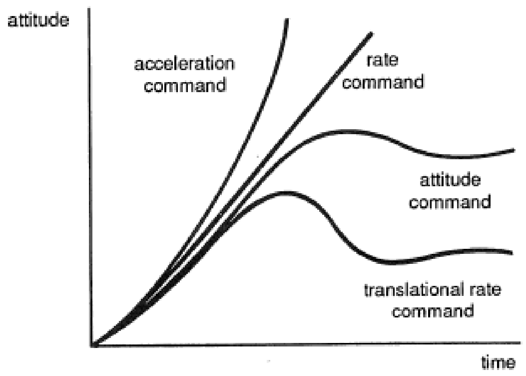

Figure 2 Attitude response type following step cyclic control input [4]

2.1.1 Simulation

ADS-33 also has provision for the use of simulators, in particular the deficiencies in performance expected when completing flying qualities assessments in a simulator environment:

> *If the Simulated Day Usable Cue Environment (SIMDUCE) is greater than one, it is likely that the pilot ratings (HQRs) will be in the Level 2 range (HQR between 4 and 6), even though the actual rotorcraft would be Level 1. The key indicator of acceptable Level 1 HQ is that the pilot comments clearly associate the Level 2 deficiencies with deficient visual cueing.*

2.2 Previous Development

2.2.1 Proposed Maritime Hover MTE

The work of Manso and Arney focused on the development of a maritime hover MTE intended to replicate requirements of a low level maritime hover in open-ocean. The proposed manoeuvre was defined as follows, with performance criteria shown in Table 1.

> **Objective**
> Check ability to maintain precise position, heading, and altitude in the presence of calm winds and moderate winds from the most critical direction.
>
> **Description of manoeuvre**
> Establish and maintain hover over the target point. For moderate wind, orient the aircraft with wind at the most critical azimuth.
>
> **Description of test course**
> Over water the manoeuvre should be flown to a fixed buoy with only open water visual references available. For baselining, the manoeuvre should be flown to an appropriate land-based target point.

Table 1 Performance criteria for the Maritime Hover MTE [1]

Criteria	Desired	Adequate
Maintain plan position within ±*X* ft of the target point	3	6
Maintain altitude within ±*X* ft	4	6
Maintain heading within ±*X* deg	5	10
Maintain hover for ±*X* min	2	2

2.2.2 Preliminary Results

In November 2007, two sorties were flown by AMAFTU pilots at Naval Air Station (NAS) Nowra and on Jervis Bay. The crew consisted of two test pilots in an AS350B Squirrel. Both the proposed maritime hover MTE and baselining ground course manoeuvres were undertaken; the latter in compliance with the ADS-33 ground hover MTE (see Appendix A).

When undertaking the maritime hover MTE each pilot employed a different strategy to maintain visual reference of the floating buoy. Both visual reference techniques are detailed in Appendix B, and are referred to as the boresighting and Diagonal Visual Reference (DVR) strategies.

Ground hover MTE flight test results over the NAS ADS-33 ground course yielded the expected results, with both pilots providing a UCE rating of 1. Desired performance was attained in altitude, plan position and heading with the Stability Augmentation System (SAS) engaged. The HQR rating degraded 1 point for altitude maintenance with SAS OUT, but desired performance was still attained.

The maritime hover MTE was rated a UCE of 2, which was anticipated. Despite excellent references for pitch and roll attitudes due to a distinct horizon, heading references were degraded when compared to the land-based environment. HQRs also degraded as expected.

Unfortunately limitations of the AOSC at the time of the AMAFTU flight trial (prior to the 2009/2010 upgrade of the facility) meant that simulation results could not provide meaningful comparison and analysis.

2.2.3 Recommendations

It was recommended that further testing be undertaken, both in the form of simulator experimentation and flight testing, to more comprehensively assess the proposed maritime hover MTE. Limitations of the data obtained during preliminary testing meant that no conclusions could be drawn as to the viability of the maritime hover MTE.

3. Pilot Study

3.1 Testing of the Proposed Maritime Hover MTE

In lead-up to the AOSC experiment, a pilot study was conducted to assess the proposed experimental method and test conditions. Much of the methodology was taken directly from Manso and Arney [1]. The aim of the experiment was to assess the proposed MTE as developed by AMAFTU within the AOSC simulator, with particular focus on determining the suitability of the simulator for undertaking such manoeuvres.

When the maritime hover MTE was flown during flight trial in 2007, pilots were asked to utilise air crewman or loadmaster conning to establish and maintain hover over the target point. Use of aircrew conning was a result of the fact the sorties were flown in the AS350B Squirrel, and as such Differential GPS (DGPS) was not available to provide pilots with real-time feedback on their plan position. Without DGPS capability, it was difficult to determine exactly what accuracy was being achieved with respect to plan position limits.

The maritime hover MTE in its proposed form did not stipulate an altitude or 'standoff' distance from the buoy during the test. Whilst it is acknowledged the customary altitude for hover over water is likely to be different for each aircraft type, both altitude and standoff distance impact the ease with which the MTE can be undertaken.

3.1.1 First Pilot Trial

The pilot study was conducted with Pilot 1[1] flying both maritime hover and ground course MTE scenarios in the AOSC simulator. Two ground course manoeuvres, the Hover MTE and Pirouette MTE (see Appendices A and C) were flown over a test course matching the ground course at NAS Nowra as per ADS-33 specifications.

The maritime hover MTE was flown without provision for conning relating to aircraft position. The pilot was asked to maintain hover using both the DVR and boresighting methods (see Appendix B), in varying sea states. As no standoff distance was prescribed by the test card, a value of 100m was initially trialled. The pilot was asked to select his preferred hover positioning before MTE limits were imposed.

Pilot performance was expected to degrade when flying ADS-33 manoeuvres in the AOSC, as the simulator is fixed-based, preventing the use of motion cues. Deficiencies also exist in fine detail of the environment such as rotor downwash or similar textural effects that can be used as positioning cues. Despite such shortcomings, Pilot 1's performance over the ADS-33 ground course was as expected. For both the Hover and Pirouette MTEs, adequate performance was attained using flight models designed to represent both the Squirrel and Seahawk helicopters. In contrast, overall adequate performance could not be attained during any of the maritime hover MTE scenarios. In particular, adequate helicopter plan position was generally lost within the first five seconds of the required two minute hover hold.

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[1] All pilots who took part in the simulator trials were qualified Test Pilots.

Pilot feedback indicated concern over the task for the following reasons:
- Fine details cues were not provided in the simulator (e.g. ocean spray/downwash).
- Lack of depth perception and motion cues.
- Suitability of MTE limits: the pilot questioned whether the proposed limits were too strict within context of the task. The ability to achieve adequate performance was further degraded by the limitations of the simulator environment[2].
- Low workload: although overall performance was poor, the fact no feedback mechanism (i.e. usable cues) existed for the pilot to assess position with respect to the MTE limits meant workload was low during the task. This issue was not captured by the Cooper-Harper HQRs.
- Task focus appeared more an assessment of the UCE rather than an assessment of the pilot workload and/or the aircraft performance itself.
- Assessing changes in heading and plan position was very difficult with only the buoy as a marker.

The overarching concern relating to the experiment was whether the maritime hover MTE as originally proposed met with the intent of ADS-33 in assessing the handling qualities of the aircraft, or whether it was simply providing an assessment of the UCE.

3.1.2 Second Pilot Trial

In response to feedback from the first trial the following changes were implemented:
- Standoff distance to buoy reduced from 100m to 50m
- Hover reference image changed from a marker buoy to a high contrast image (see Figure 3) intended to provide improved heading and plan position reference.
- Clouds were also added to the sky of the scenario to improve available cues.

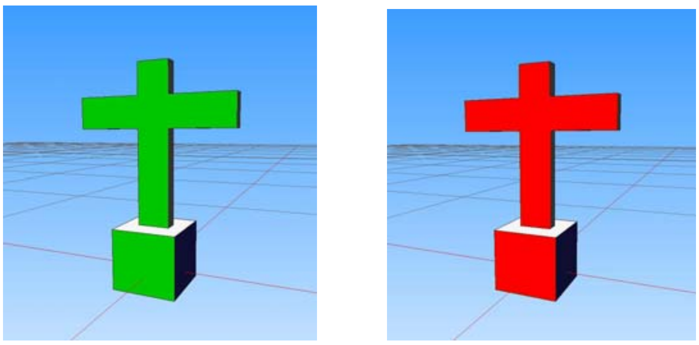

Figure 3 High contrast target used in place of a marker buoy during the pilot study

A second test session was held to assess what impact, if any, was evident from changes to the available visual cues. Although the HQRs did not alter significantly from the initial trial, the pilot reported that the task was more manageable. As the aspect and size of the marker was

[2] It should be noted that whilst a Squirrel flight model was tested, DSTO does not have a Squirrel cockpit. As such, all testing was completed in the MRH 90 cockpit.

the only available cue for detecting changes in plan position and heading, the visual aspect became more important than the fidelity of the flight model given the inherent limitations of the simulator.

As previously, the major issue with completing the task in the simulator was the lack of available cues to provide feedback on changes to heading and plan position, which yielded low pilot workload, but resulted in higher than anticipated HQR evaluations.

The second trial also raised the question as to whether the limits of the maritime hover MTE were actually perceptible since the pilot was relying solely on limited visual cues. Given the only reference for maintaining hover position was the marker; pilots were effectively being asked to assess the change in the relative aspect of the marker to detect a change in position of the aircraft. The results suggested that pilots were potentially unable to discriminate a change of ±3 ft/±6 ft at a standoff distance of 50m in a low contrast, low content environment.

This concern was investigated experimentally prior to the final trial.

3.2 Visual Perception Threshold Limitations in the AOSC Simulator

A full report of the visual perception threshold experiment is provided by Parker [5], with only a summary of key results presented here.

The experiment tested whether or not a change of 3 ft between the aircraft and the buoy, at standoff distance of 50 m and altitude of 50 ft, was large enough to be detected visually. The aim was to determine the minimum distance the aircraft must move from its original position for a change in position to be perceived. This minimum distance was defined as the distance discrimination threshold.

Participants were required to identify whether images of a buoy shown in the AOSC flight simulator were 'closer' or 'farther' than the image of the buoy at the baseline distance of 50 m. The experiment was conducted for calm seas, as well as at a moderate sea state (representative of sea state 3/4). Figure 4 shows the percentage of correct responses for each data point[3]. Any point with a percentage less than 50% was considered a response no longer correct more often than would be achieved by guessing.

[3] Data point definition and information are provided in Appendix D.

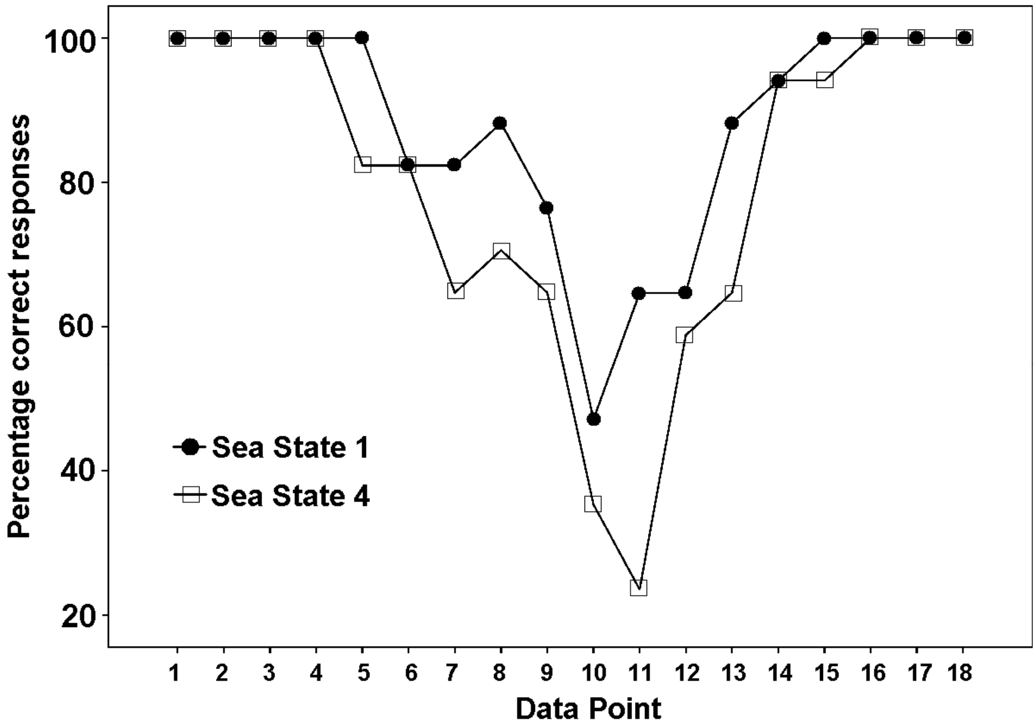

Figure 4 Percentage of correct responses for each data point [5]

In order to determine the visual perception thresholds, data fitting using the Weibull cumulative distribution function [6] was applied to the mean data to find the underlying psychometric function (s-curve) to fit the data. Figures 5 and 6 show the fitted curves. The 25% and 75% values of the Weibull fitted curves correspond to the upper and lower thresholds of the data set.

It was concluded that participants could not reasonably determine whether they had moved closer or further from the buoy:

- For calm seas when the change was less than +0.97 m (3.18 ft) to -0.45 m (1.48 ft) from the standoff distance

- For moderate seas when the change was +2.17 m (7.12 ft) to -0.95 m (3.12 ft) from the standoff distance

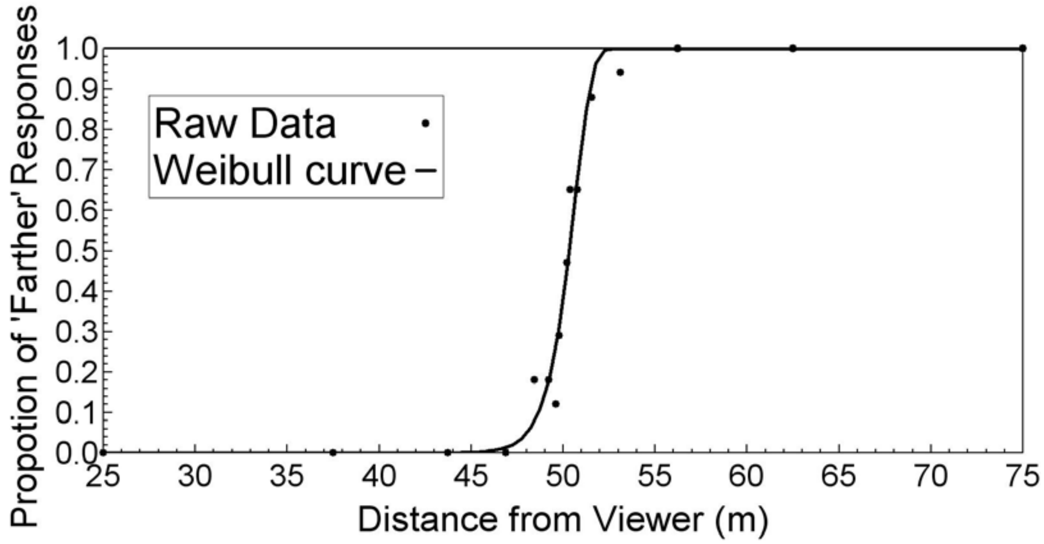

Figure 5 Fitted Weibull curve for calm sea responses [5]

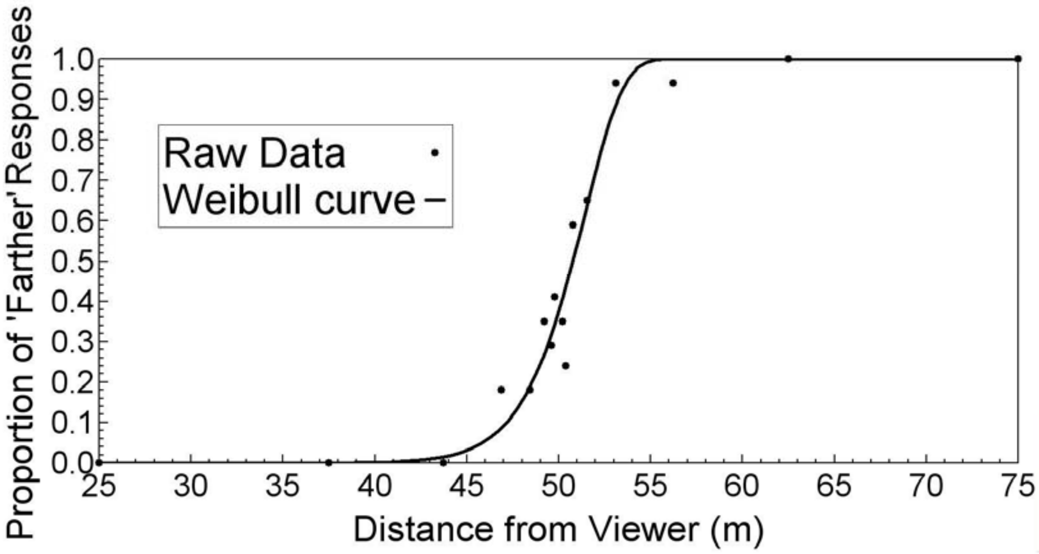

Figure 6 Fitted Weibull curve for moderate sea responses [5]

It should be noted that this experiment sought to identify visual perception thresholds, but the application of these results to a maritime hover must take into account the fact that pilots are not constantly given reference to their original hover position – they must hold the same position with reference to the perceived change in the buoy aspect for two minutes. Furthermore, pilots must maintain altitude and heading in conjunction with plan position. Such a task load will almost certainly impede distance perception to some degree.

Based on these results, it was determined that desired performance could not be reasonably attained in the AOSC simulator with the original MTE limits and proposed standoff distance.

3.3 Transition to an Alternate Maritime Hover Manoeuvre

The pilot studies raised two key issues:

1. Whether the proposed maritime hover task could meet the original intent of the ADS-33 specification, or whether it was restricted to a measure of the effect in changes to the UCE.
2. Performance limits were likely to be unachievable given the threshold of visual acuity in the simulator.

Both concerns were raised in discussion with AMAFTU, and the outcomes are detailed in the following sections.

3.3.1 Legitimacy of the Maritime Hover MTE

The intent of any ADS-33 manoeuvre is to enable an assessment of a rotorcraft's handling qualities. This is the fundamental purpose of any MTE. In the case of the proposed maritime hover MTE, the primary driver for development was Search and Rescue (SAR) operations. To maintain station during SAR in the absence of visual reference to the target, pilots receive positional cueing (referred to as conning) from aircrew/loadmasters in relation to the aircraft's position over the target. As such, a maritime hover task replicating SAR would not provide a direct assessment of the handling qualities of the aircraft.

The maritime hover MTE as proposed and tested in the simulator did not allow for conning. AMAFTU also raised concern over how accurately the manoeuvre could be assessed during flight trial without DGPS. It was suggested that conning could be replaced by additional visual cues (multiple buoys) but the legitimacy of such an assumption could not be assured. Introducing additional visual positioning cues had the added effect of moving the manoeuvre further away from operational reality.

The only difference between a ground-based hover manoeuvre and an open-ocean hover manoeuvre is the UCE, and as such the degradation in UCE simply assesses the effect on the pilot, not the handling qualities of the aircraft[4]. Despite this, the complexity of the maritime environment cannot be appropriately replicated using ground course conditions, which in turn leads to the legitimate question of how accurately a pilot can maintain station based on the visual environment.

In recognition of the fact that the proposed Maritime Hover Manoeuvre MTE did not meet the intent of ADS-33, but still provided useful information about the effects of UCE, an alternate maritime hover manoeuvre was recommended for testing in the AOSC.

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[4] Noting that a reduction in UCE might of itself reveal handling qualities difficulties if the pilot changes his/her control strategy to compensate.

3.3.2 Proposed Maritime Hover Manoeuvre

In consultation with AMAFTU, the maritime hover manoeuvre limits were revised to reflect changes to the experimental intent, as detailed in Table 2. Most notably it was decided that plan position limits would be rates-based rather than position-based, and time on station reduced from two minutes to 30 seconds. Both changes more realistically reflect operational performance requirements. AMAFTU pilots noted that flight tests would be likely to recommend that the rates-based plan position limits be reduced given capabilities of the aircraft, but that the limits as nominated in Table 2 were suitable for the simulation trial and preliminary testing.

During SAR operations pilots are not expected to hold absolute position, or to regain the initial hover position, instead the most critical element is a stable hover. Given pilots do not have visual reference on the target, and the target does not hold fixed position in the water, accurate positioning relies on conning. In general terms, 30 seconds is representative of the longest period a pilot would hold position without receiving a conning instruction from the air crewman.

Table 2 Performance criteria for the maritime hover manoeuvre

Criteria	Desired	Adequate
Maintain plan position rates within ±X ft/sec of the target point	3	6
Maintain altitude within ±X ft	4	6
Maintain heading within ±X deg	5	10
Maintain hover for ±X sec	30	30

For purposes of the simulator trial, the manoeuvre was defined as follows:

Objective
Check ability to maintain precise heading and altitude, and minimise positional rate changes in calm, moderate and rough seas.

Description of manoeuvre
Establish and maintain hover over the target point for a period representative of the time between position data updates from the air crewman.

Description of test course
Over water the manoeuvre shall be flown to a fixed buoy with only open water visual references available. For baselining, the manoeuvre shall be flown to an appropriate land-based target point.

For the flight trial of the maritime hover manoeuvre it was proposed that a target point be identified and the pilot asked to take up position over the target[5], with a buoy located approximately 40m away on a 45° bearing as outlined in Figure 7. The exact hover position

[5] No target point was required for simulator trials as the pilot could be accurately moved into position using range-to-target information.

would then be chosen by each pilot, and the limits applied from that point noting that as per operations, the pilot should not have a visual on the target beneath the aircraft.

It is envisaged that performance limits for a maritime hover task would be a function of both altitude and sea state, but such information is reliant upon results of flight testing. In the absence of flight trial data, the limits as described in Table 2 were applied with altitudes chosen to reflect AS350B Squirrel over-water hover heights.

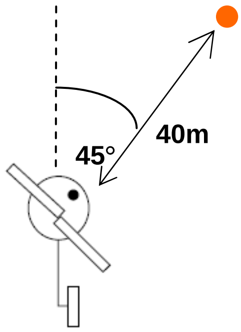

Figure 7 Proposed flight trial hover strategy

The three main concerns relating to the flight test task include the accuracy of performance assessment, the repeatability of the manoeuvre given the effect of changing meteorological conditions, as well as the reliability of results obtained. These concerns can only be addressed by AMAFTU and are considered beyond the scope of this report.

4. AOSC Experiment

The objective of the AOSC experiment was to assess the viability of a maritime hover manoeuvre and the feasibility of further development toward an ADS-33 MTE; determine a relationship between UCEs and sea conditions; and investigate the fidelity of the DSTO simulator as a means for providing UCEs.

The experiment was conducted with three AMAFTU test pilots. The maritime hover manoeuvre was tested with both the AS350B Squirrel flight model, and the S-70B Seahawk flight model.

4.1 AOSC Setup

4.1.1 EOS Displays

AOSC staff monitored a display in the EOS (Experiment Operator Station) which displayed the aircraft's altitude, heading and plan position with respect to the performance limits of the manoeuvre being performed. The display was updated in real-time by the AOSC simulation system.

Shown in Figures 8 and 9 are examples of the EOS displays for the manoeuvre limits. To enable pilot performance to be monitored for the duration of the manoeuvre, the instantaneous aircraft position was noted in black, with the position furthest from the manoeuvre start point shown in grey. In the case of the plan position display, the black icon also rotated to indicate aircraft heading. The purple diamond near the plan position display in Figure 8 shows the location of the marker buoy.

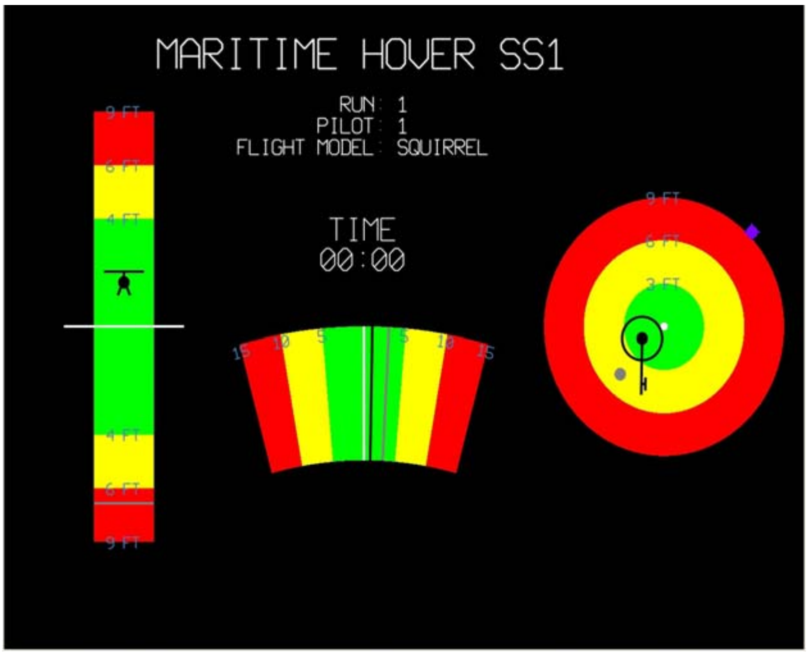

Figure 8 Still image of the Maritime Hover EOS display

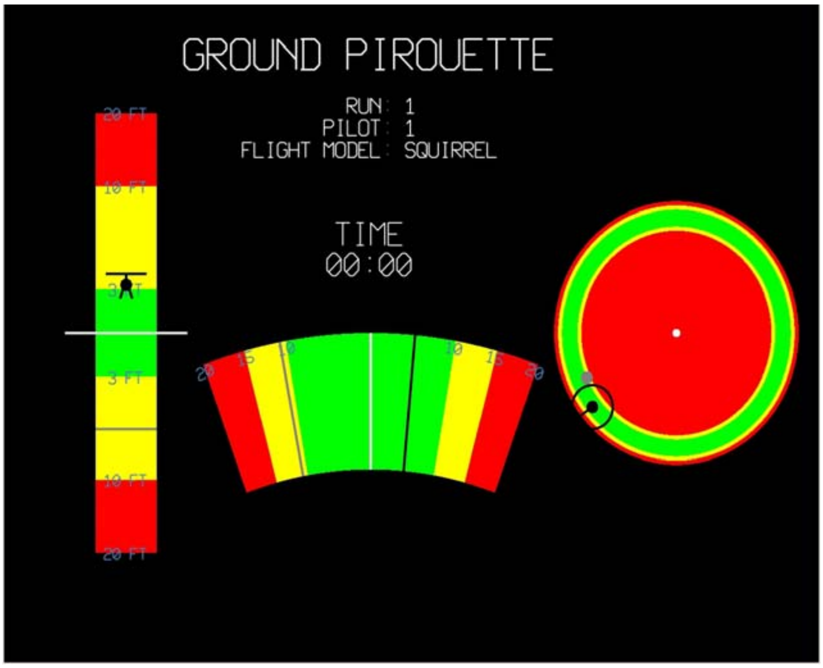

Figure 9 still image of the Pirouette MTE EOS display

4.1.2 Rotor Downwash Model

To increase the available visual cues in the environment a rotor downwash model was added. This was an animated texture, as seen in Figure 10, applied to the ocean surface. The radius of the rotor downwash animation was 25 m and based on feedback from pilots, the downwash centre point was offset with a 2.5 sec lag. That is, the rotor wash centred on the position the aircraft had held 2.5 sec ago. Once the aircraft's altitude was above 20 m the rotor wash linearly reduced in size until it disappeared at an altitude of 27.5 m.

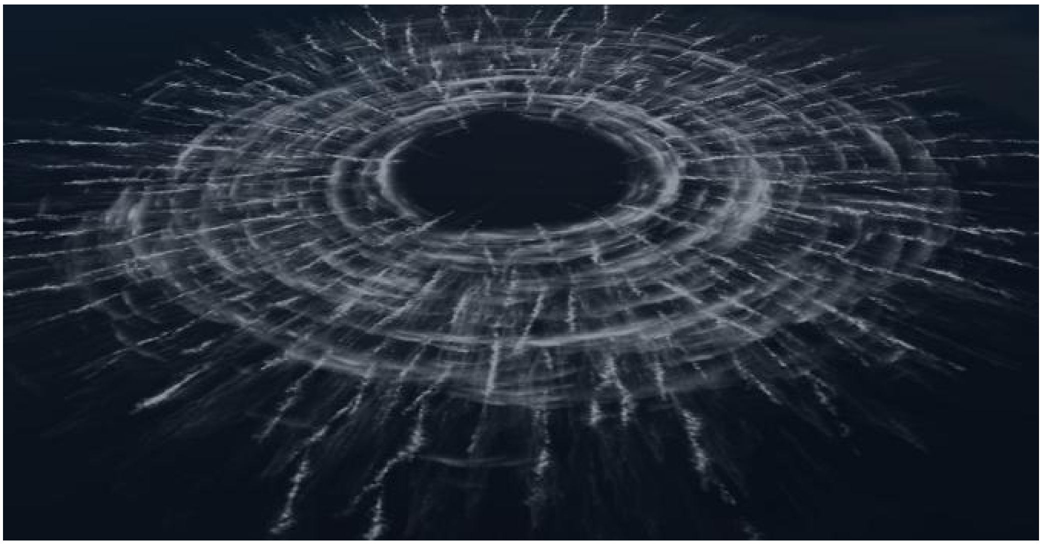

Figure 10 Still image of the animated rotor wash texture applied to the ocean

4.1.3 ADS-33 Ground Course and Open-Ocean Scenarios

Figure 11 shows the airfield where the ADS33 course was situated, which measured 1400x1400 m. The airfield was configured to disappear when the helicopter was 2 km away from the centre. This ensured that the maritime hover manoeuvre was undertaken in open-ocean positions, without pilots needing to orient themselves to ensure the island was not in sight.

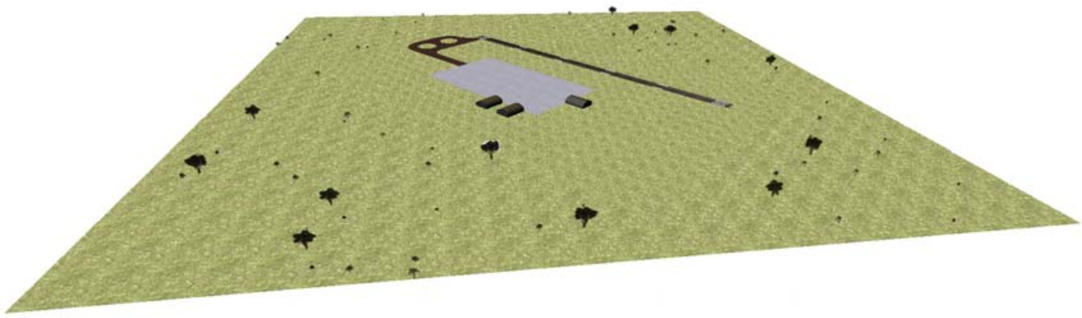

Figure 11 Simulated airfield

The ADS-33 ground course was originally developed to match specifications as per the ADS-33 document, but was altered slightly to more closely resemble the course at HMAS Albatross (as seen in Figure 12). These were only minor variations in the placement of the cones arising from some ambiguity in the ADS33 specification. The simulation course had increased lateral spacing between the cones seen in the bottom right corner of Figure 12.

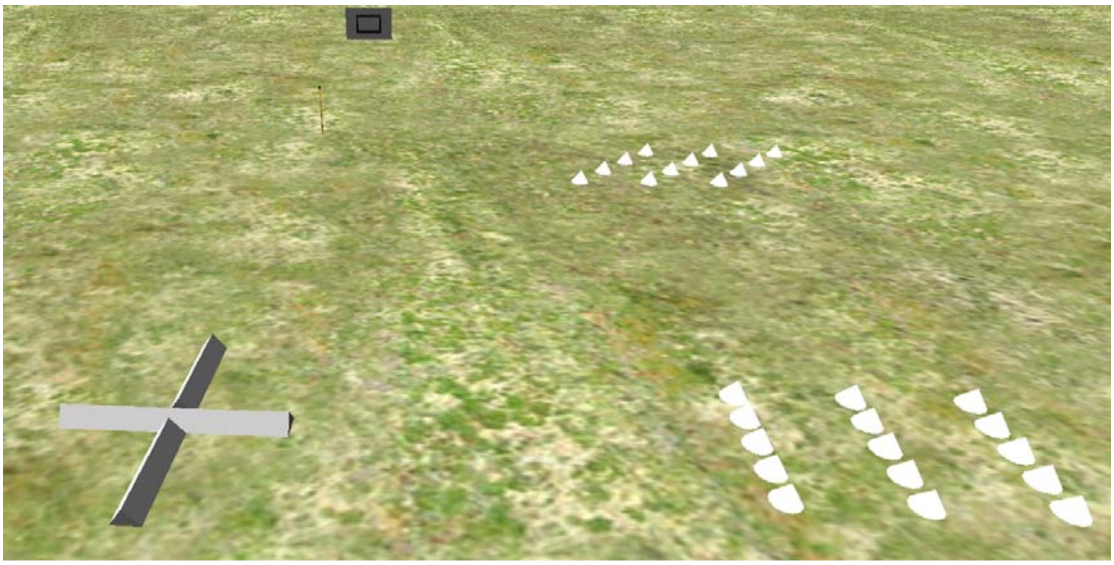

Figure 12 Detail of simulated airfield ADS-33 Pirouette course

The 3D buoy model was developed from an image of a navigational buoy, as seen in Figure 13. The buoy model was 5 m wide at the base and 10.5 m above sea level.

Figure 13 Navigational buoy (left) and the 3D buoy model used for the simulator trial (right)

4.1.4 Cockpit

Testing with both the AS350B Squirrel flight model and S-70B Seahawk model was completed in the MRH 90 cockpit with only basic instruments displayed. It is acknowledged that this arrangement provided a significant deficit in attainable fidelity for each flight model, but the experiment did not intend to assess the fidelity of the flight models individually. The flight models were simply required to be representative of a light utility helicopter and a medium weight cargo helicopter respectively, providing pilots with the feedback they would expect for each helicopter class.

4.2 Flight Models

Both flight models were developed in FLIGHTLAB[6], which has the inherent ability to model a range of helicopter types for real-time simulation.

The Seahawk flight model has been in use for over ten years and is considered a high fidelity, validated model. It is derived from the Black Hawk flight model [7]. The Squirrel flight model [8] was developed specifically for this trial, and as such had only undergone preliminary validation. It is considered a medium fidelity model.

[6] FLIGHTLAB is a commercial tool developed by Advanced Rotorcraft Technology Inc. for rotorcraft modelling and analysis.

4.3 Scenarios

Scenarios were abbreviated as per Table 3.

Table 3 Scenario abbreviations

Scenario	Abbreviation
Maritime Hover, calm seas	MH1
Maritime Hover, moderate seas	MH2
Maritime Hover, rough seas	MH3
Ground course hover (modified ADS-33 MTE)	GH
Ground course pirouette MTE	GP
Diagonal Visual Reference strategy	DVR
Boresighting reference strategy	BST

4.3.1 Maritime Hover Manoeuvre

To complete the maritime hover manoeuvre in the simulator, pilots were directed to fly to the buoy and were provided distance-to-target conning until they were satisfied with their hover position. Pilots selected their hover point using the trigger button on the cyclic control, and manoeuvre limits were then applied to that datum. DSTO staff located in the EOS then monitored performance within manoeuvre limits to enable completion of a Cooper-Harper HQR and associated Visual Rating Cue (VCR) ratings at the end of each manoeuvre.

In the absence of flight test data to inform manoeuvre specifications, the hover height prescribed for the maritime hover manoeuvre was based on advice from AMAFTU. The Squirrel is typically operated at a 15 ft hover, the Seahawk at 60 ft. To maintain continuity between results for the two platforms, as well as the UCE, pilots were directed to maintain a 15 ft hover.

4.3.2 Baseline Manoeuvre

The baseline manoeuvres for the experiment were undertaken on the ADS-33 test course. The pirouette MTE was completed as per specification (see Appendix C for details); however, the baseline ground hover manoeuvre omitted the transition from translational flight to a stabilised hover to ensure continuity between the objectives of both hover manoeuvres.

As noted in the ADS-33 specification, inherent limitations of current simulator technologies result in an anticipated degradation in pilot performance when compared to flight test results. The baseline pirouette and modified ground hover MTEs provide a benchmark both for the maritime hover manoeuvre, and for the UCE fidelity provided by the simulator.

4.4 Performance Assessment and UCE

At the completion of each scenario, pilots were asked to provide VCRs and specify HQRs as per the Cooper-Harper Rating scale.

4.4.1 Use of the Cooper-Harper Rating Scale

Preliminary testing raised concern over the use of the Cooper-Harper rating scale for the maritime hover manoeuvre. Pilots noted that insufficient visual cues resulted in an inability to judge their performance with respect to performance limits during the task. The degraded UCE of the simulator had the effect of decoupling workload from task performance.

It was acknowledged that given the maritime hover manoeuvre was not intended as an ADS-33 MTE, the HQRs were simply a reflection of task accuracy and that workload did not change between the maritime hover scenarios. To this end, and in the absence of a more appropriate method for assessing task accuracy, the Cooper-Harper rating scale was applied to the maritime hover scenarios with the caveat that results are not a true representation of HQRs as required by ADS-33.

4.4.2 UCE Ratings

In order to allocate a UCE for each scenario, pilots rated the visual environment using the VCR scale specified by ADS-33. Detailed in Figure 14, pilots were asked to provide ratings for attitude (roll, pitch and yaw) and translational rate (horizontal and vertical).

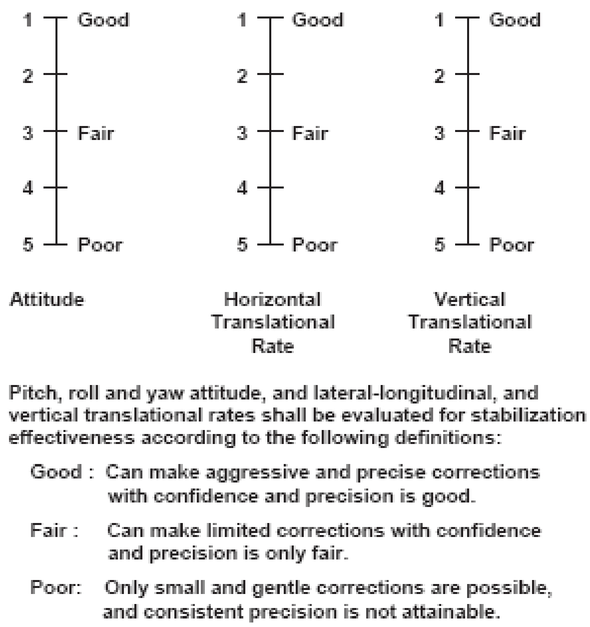

Figure 14 ADS-33 Visual Cue Rating Scale

As per ADS-33 specification[7], mean VCRs were used to determine the UCE using the chart shown in Figure 15.

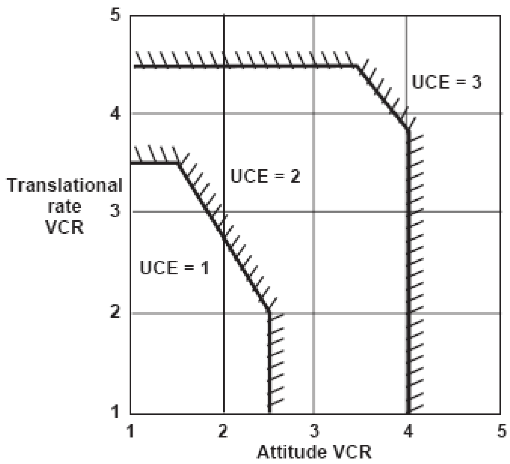

Figure 15 ADS-33 Usable Cue Environment for Visual Rating Cues

[7] The VCRs shall be made by at least three pilots using the scale shown in Figure 14. The mean VCRs for each task shall be obtained by separately taking the average of all the pilot ratings in each axis. This will result in five average VCRs for each task: pitch, roll, and yaw attitude, and vertical and horizontal translational rate. This shall be reduced to two VCRs by taking the worst (numerically highest) average VCR among pitch, roll and yaw attitude, and between vertical and horizontal translational rate, for each task. These VCRs for attitude and translational rate shall be plotted on Figure 15 to obtain a UCE for each task.

5. Results

Each scenario was repeated three times using the Squirrel flight model and twice for the Seahawk flight model to ensure consistency of pilot responses and to allow identification of training effects. The scenario test matrix was randomised for each pilot, although this did not extend to randomisation of the flight model in use due to the overhead associated with loading flight models between scenarios. Pilot feedback during initial testing also indicated that continual switching between models was not ideal given limitations of the simulator environment and the resulting time taken for pilots to become accustomed to each model. Pilots also requested that the downwash animation be removed from the scenarios as it initially proved more a hindrance than an improvement in the fine detail visual cues.

The full result set is provided in Appendix E (Squirrel flight model) and Appendix F (Seahawk flight model), showing plan position, heading and altitude data with respect to manoeuvre limits. For a small number of test cases the data files were incomplete, and as such could not be included in the analysis.

Plan position results are presented as geometry outlining the maximum deviation of the aircraft[8]. Figure 16 provides an example of the raw data being encompassed by a representative perimeter, and how this is then graphed with respect to manoeuvre limits.

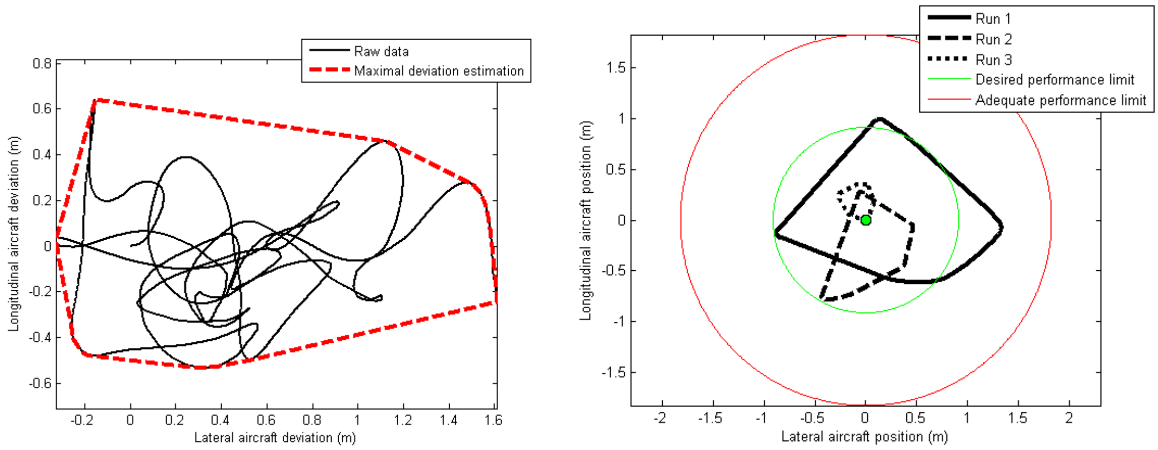

Figure 16 Example of results presentation – aircraft plan position

Results for the aircraft heading and altitude deviation during the manoeuvre are shown as box plots[9], with outliers shown in red. An example is provided in Figure 17.

[8] In the case of the ADS-33 Pirouette manoeuvre, the raw data is plotted with respect to the manoeuvre limits.
[9] Box plots represent the data in terms of basic statistics, which include the minimum and maximum values in the data set, and the upper, middle (median) and lower quartiles.

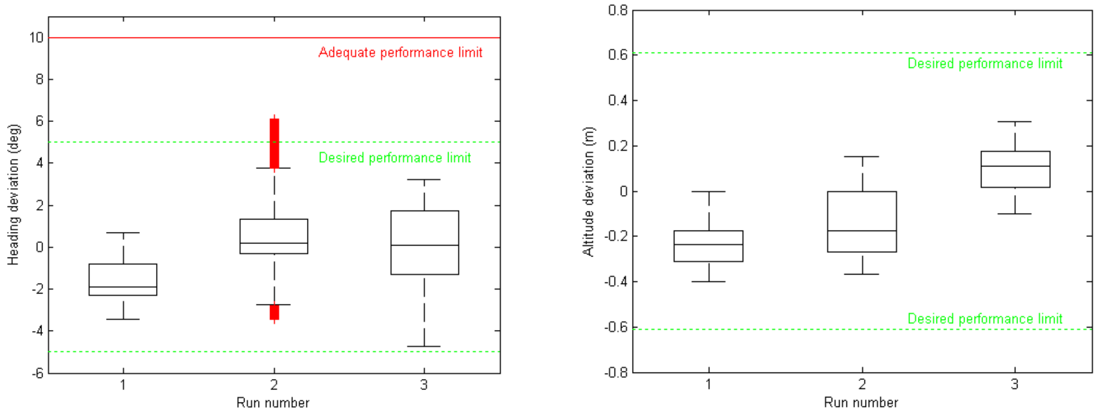

Figure 17 Example of results presentation – aircraft deviation for heading and altitude

Pilots reported that altitude was generally not difficult to maintain, noting that use of the MRH 90 cockpit with the Squirrel flight model did allow for the collective to be effectively 'trimmed out'. No such collective setting is possible in the real aircraft, but pilots indicated that there is generally low workload associated with collective control in the Squirrel and it would be unlikely to invalidate the results gathered in the simulator.

5.1 Baseline

Results for performance over the ground course were consistent for all pilots. The UCE was rated 2 for both the pirouette MTE and modified ground hover on the ADS-33 test course. HQRs were also consistent, with both manoeuvres rated at Level 2.

These results confirmed the expectations of baseline testing. Given the SIMDUCE rating of 2 and HQR assessment of Level 2, the actual aircraft should be capable of returning Level 1 handling qualities. This is supported by the fact that both the Squirrel and Seahawk helicopters yield Level 1 performance during equivalent ground-based flight testing.

Results confirmed the AOSC simulator to be of suitable fidelity for use in these scenarios, despite the fact that the Squirrel flight model has not undertaken extensive validation.

5.1.1 Training Effects

The ground-based hover manoeuvres clearly identified training effects, with the performance of most pilots improving over the course of the experiment. This is also supported when comparing the results of the Squirrel flight model with that of the Seahawk. As testing with the Squirrel model was completed first, there is greater consistency in the Seahawk results as pilots were by this stage more familiar with the simulator environment. Figure 18 demonstrates these differences. Whilst it is acknowledged training effects were present during the experiment, given the purpose of the trial the randomisation of the scenarios was considered sufficient to minimise the impact on results analysis.

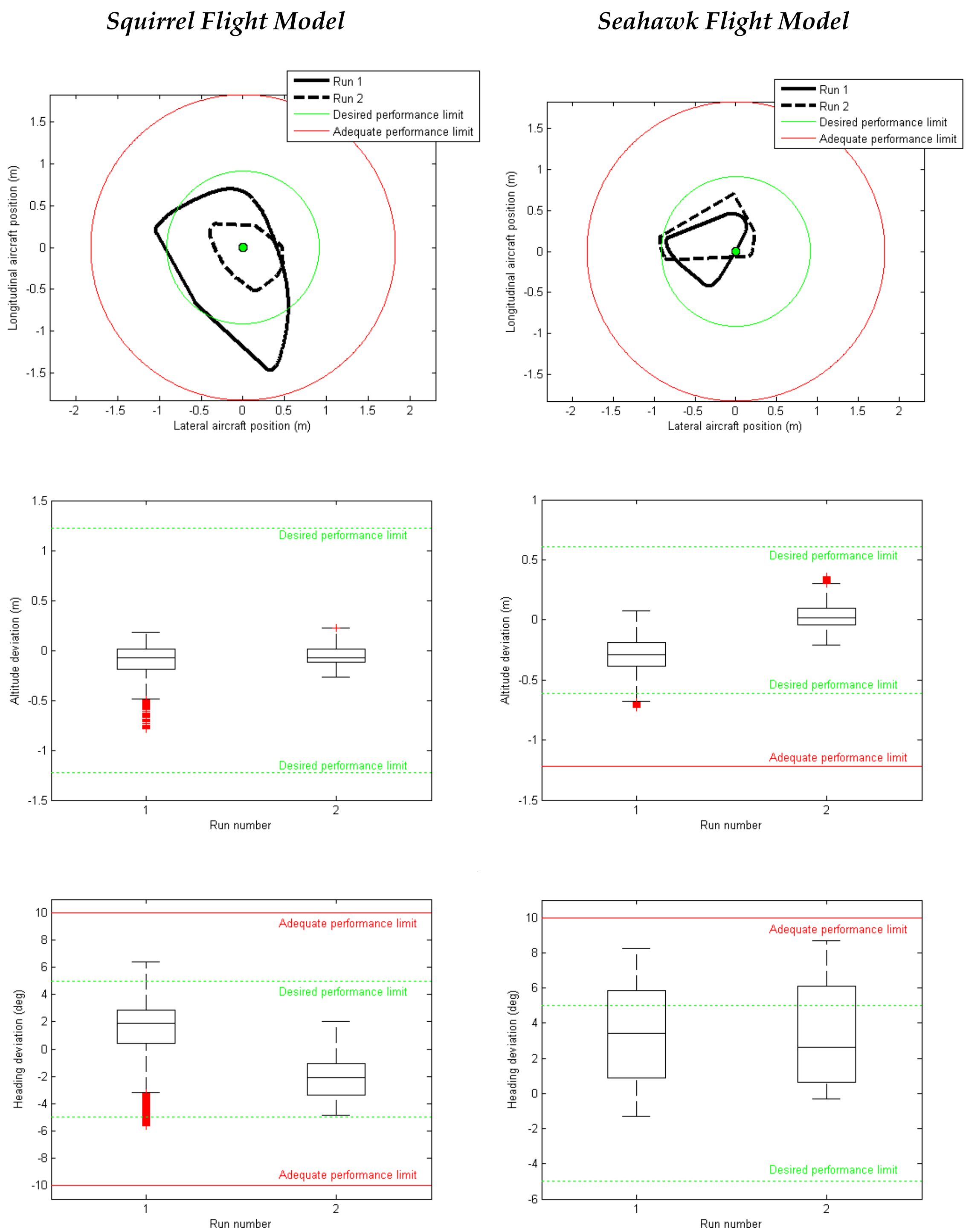

Figure 18 *Maximum deviation of aircraft plan position, altitude and heading during the ADS-33 Ground Hover manoeuvre, showing results for the Squirrel and Seahawk flight models (Pilot 4)*

5.1.2 Additional Testing

Further testing was completed for the ground-based hover scenarios with pilots directed to maintain a precise hover at a point away from the ADS-33 ground course[10]. The pilots reported that this task was less demanding when compared to the modified ADS-33 ground hover task, with reduced the occurrences of Pilot Induced Oscillations (PIO). Due to the fact that the pilots were not required to maintain a prescribed hover point, the cognitive workload decreased, which when coupled with a UCE sufficient for the task[11], enabled the hover to be more accurately maintained.

A comparison between the performance during ground-based hover, both on and off the ADS-33 test course, is provided in Figure 19. Despite pilots noting they found it easier to hold a hover position away from the ADS-33 course, there is no significant difference in the results[12]. As with the ground hover manoeuvre undertaken on the ADS-33 ground course, the UCE rating was 2 and the HQR Level 2.

Conversely, a stark contrast is evident when comparing the results of drift rate for MH1 using the boresighting reference strategy and ground hover away from the ADS-33 course on the simulated airfield. In essence each manoeuvre is identical, with the only difference being the UCE of the ground environment compared to the UCE of the open-ocean. Results are shown in Figure 20, with the maritime hover manoeuvre limits applied in each case. Compared with the open-ocean scenarios, the land environment was feature-rich, and pilots were able to utilise the chin bubble and ground textures to better monitor changes in aircraft position. The improvement in performance is marked, but the UCE ratings were the same for both scenarios (each was rated a UCE of 2). This highlights the inability of the current ADS-33 specification to identify the UCE difference between land-based and maritime conditions, despite the fact the maritime environment is clearly a degraded UCE.

To this end, the results displayed in Figure 20 show that the AOSC simulator is capable of replicating differences in the UCE between the ground and maritime environments. Although simply a comparison of the available visual cues, it nonetheless confirms the expectation that the UCE degradation makes it more difficult to maintain station in a maritime hover than for the land-based equivalent.

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[10] ADS-33 ground course hover performance limits were applied to assess the manoeuvre.
[11] In this case ground texture visual cues.
[12] Only plan position results are shown here, full results are provided in Appendix G.

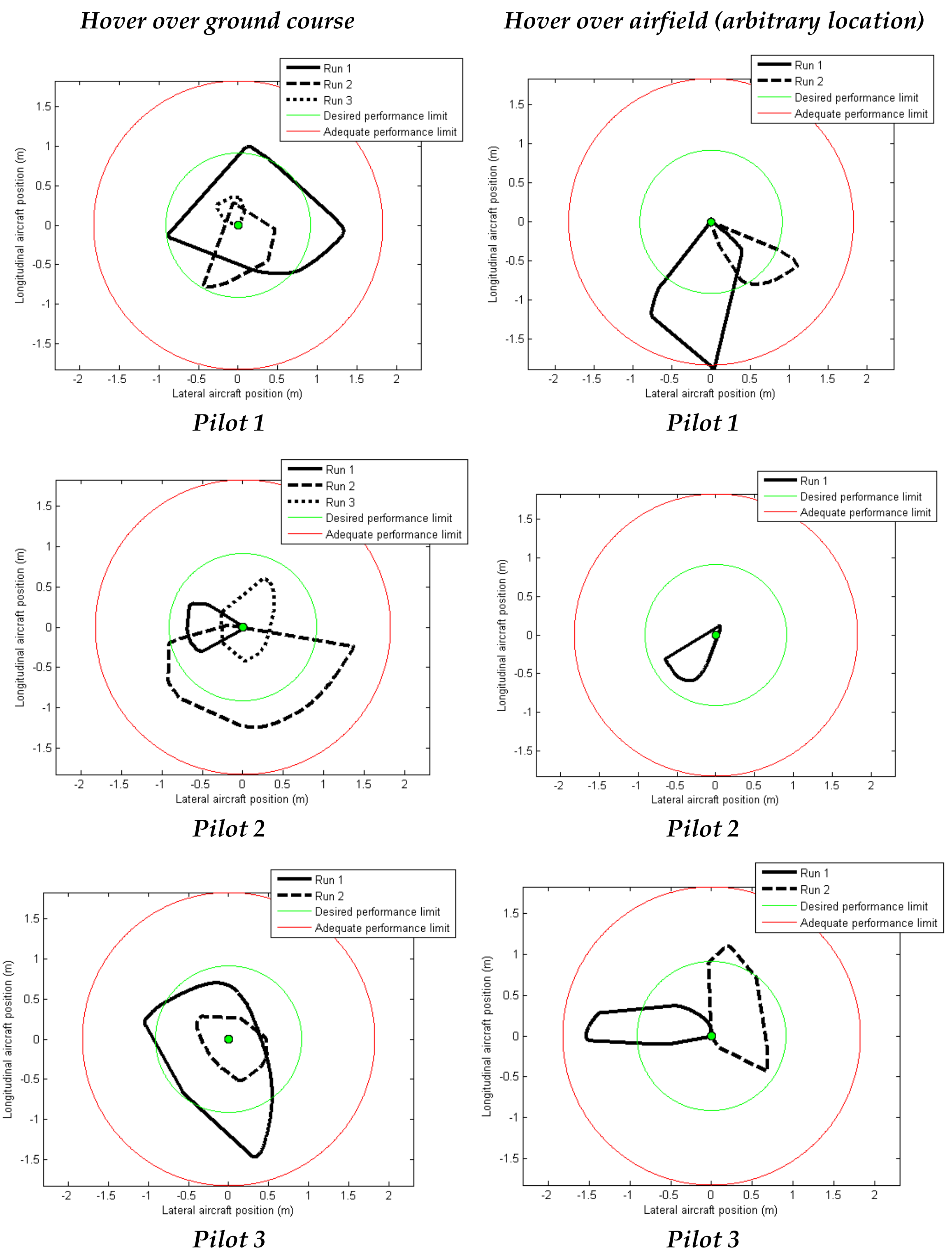

Figure 19 Maximum deviation of aircraft plan position during a modified ADS-33 Ground Hover manoeuvre: on the ground course, and using arbitrary features of the simulator airfield

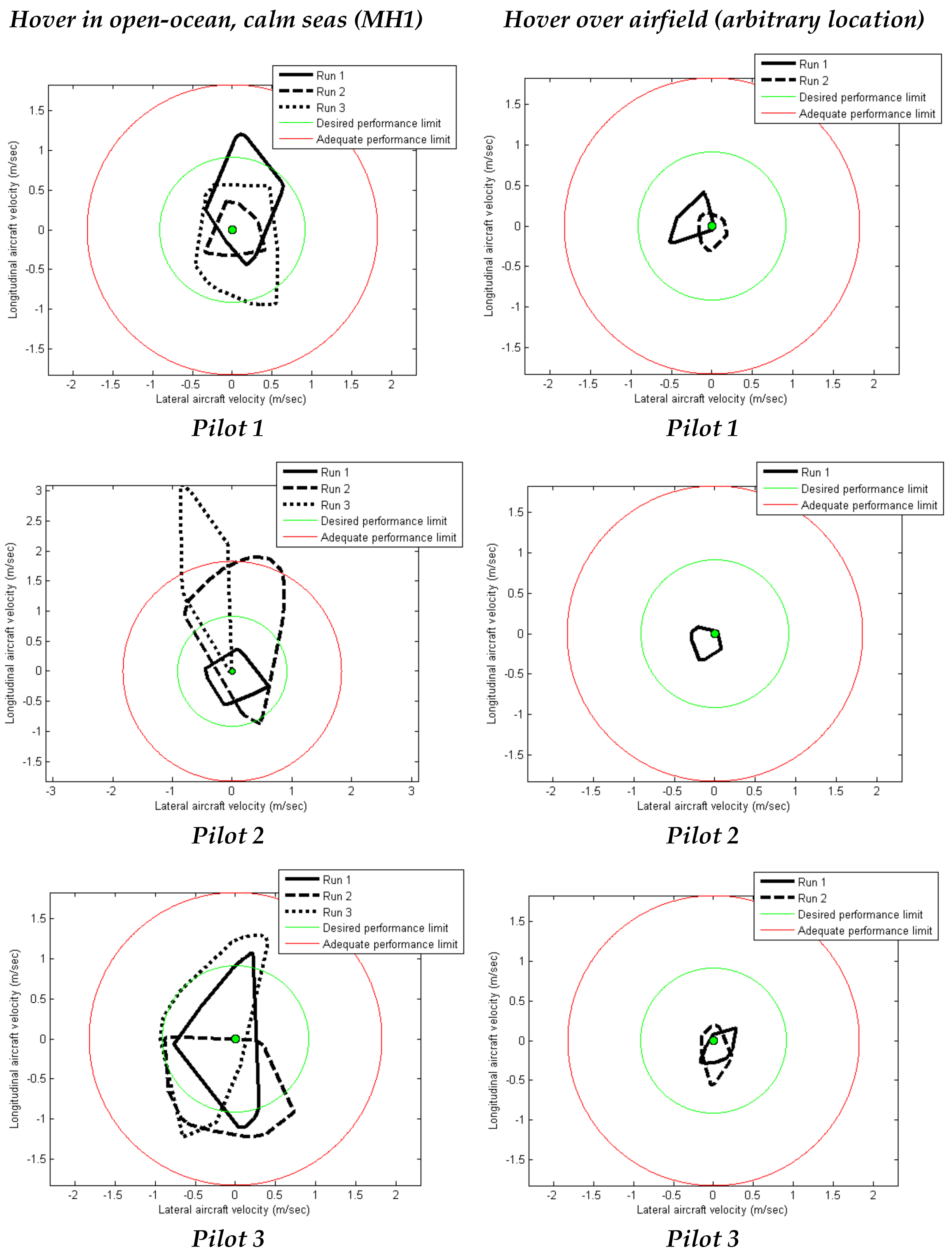

Figure 20 *Maximum aircraft drift rate for MH1 using the boresighting reference strategy, and during a modified ADS-33 Ground Hover manoeuvre on the simulator airfield*

5.2 Maritime Hover Manoeuvre

Results for each maritime hover scenario are shown in Table 4. The results apply equally to Squirrel and Seahawk flight models. Although qualitative pilot feedback indicated that the Seahawk flight model was more stable and less prone to PIO, overall HQRs differed by only 1 HQR on average. This is not unexpected given the performance range encompassed by each rating.

As noted previously, there is a significant caveat when considering the HQR assessments completed during the maritime hover manoeuvre.

Table 4 UCE Ratings and HQRs for the maritime hover manoeuvre

Scenario	UCE	HQR[13]
MH1 (DVR)	2	Level 2/3
MH1 (BST)	2	Level 2/3
MH2 (DVR)	2	Level 2/3
MH2 (BST)	2	Level 2/3
MH3 (DVR)	2	Level 2/3
MH3 (BST)	2	Level 2/3

5.2.1 Reference Strategies and the Effects of Changing Sea States

The analysis that follows has been completed for the Squirrel flight model only, as the differences in results for the Seahawk flight model are not considered significant. All results are provided in Appendices E and F. Altitude and heading results are not shown here, as drift rate most commonly dictated the overall performance with respect to the manoeuvre limits.

In calm seas (MH1), the boresighting reference strategy appeared more successful than DVR, as shown in Figure 21. This was expected, as the buoy could be aligned with other features of the simulation environment, most notably the horizon.

Figure 22 shows the results for moderate seas (MH2). With an increase in swell, the DVR strategy appears more accurate than the boresighting technique.

In rough seas (MH3), Figure 23, the anticipated degradation in overall performance is evident and there is no clear difference between the two reference strategies. Of the two, the DVR method seems to result in less significant drift rates, but control in all axes does suffer considerably under such conditions. It is unlikely that this scenario would be undertaken operationally in an aircraft without upper-mode control (i.e. heading/altitude hold) as pilot workload is very high when left with only basic SAS functionality.

[13] Noting that this rating does not include a meaningful workload assessment.

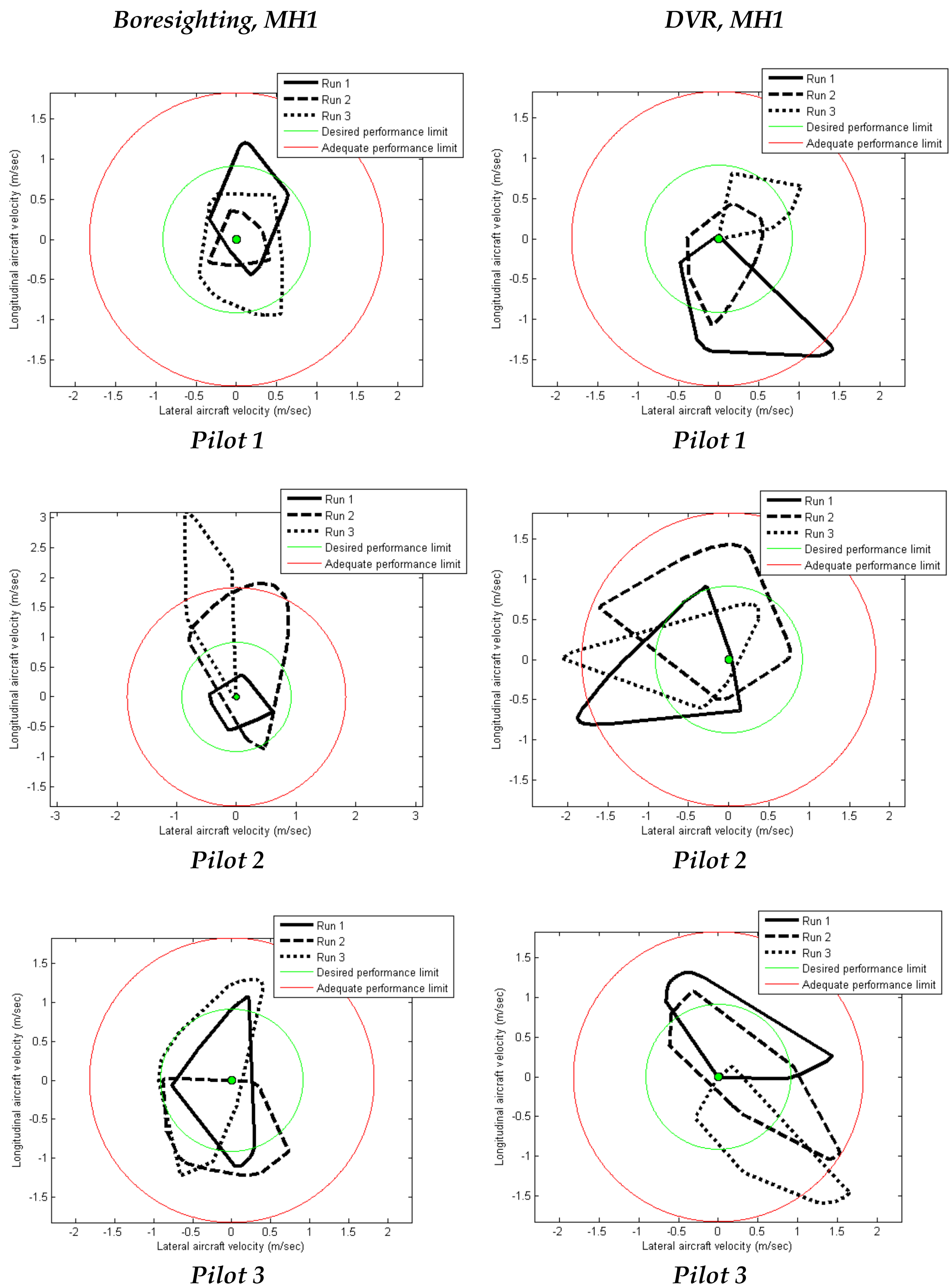

Figure 21 Maximum aircraft drift rate during MH1 using Boresighting and DVR strategies

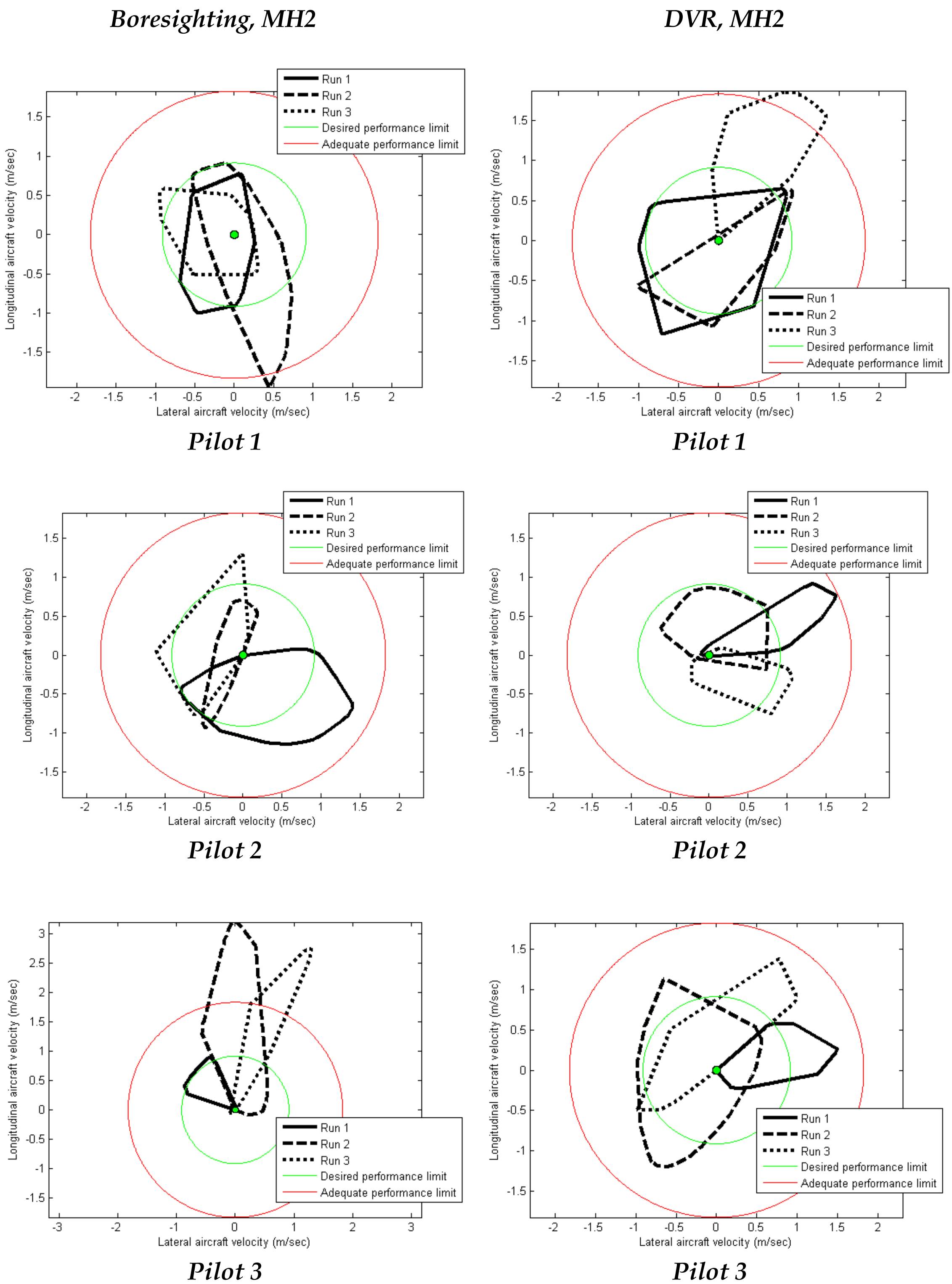

Figure 22 Maximum aircraft drift rate during MH2 using Boresighting and DVR strategies

Boresighting, MH3 ***DVR, MH3***

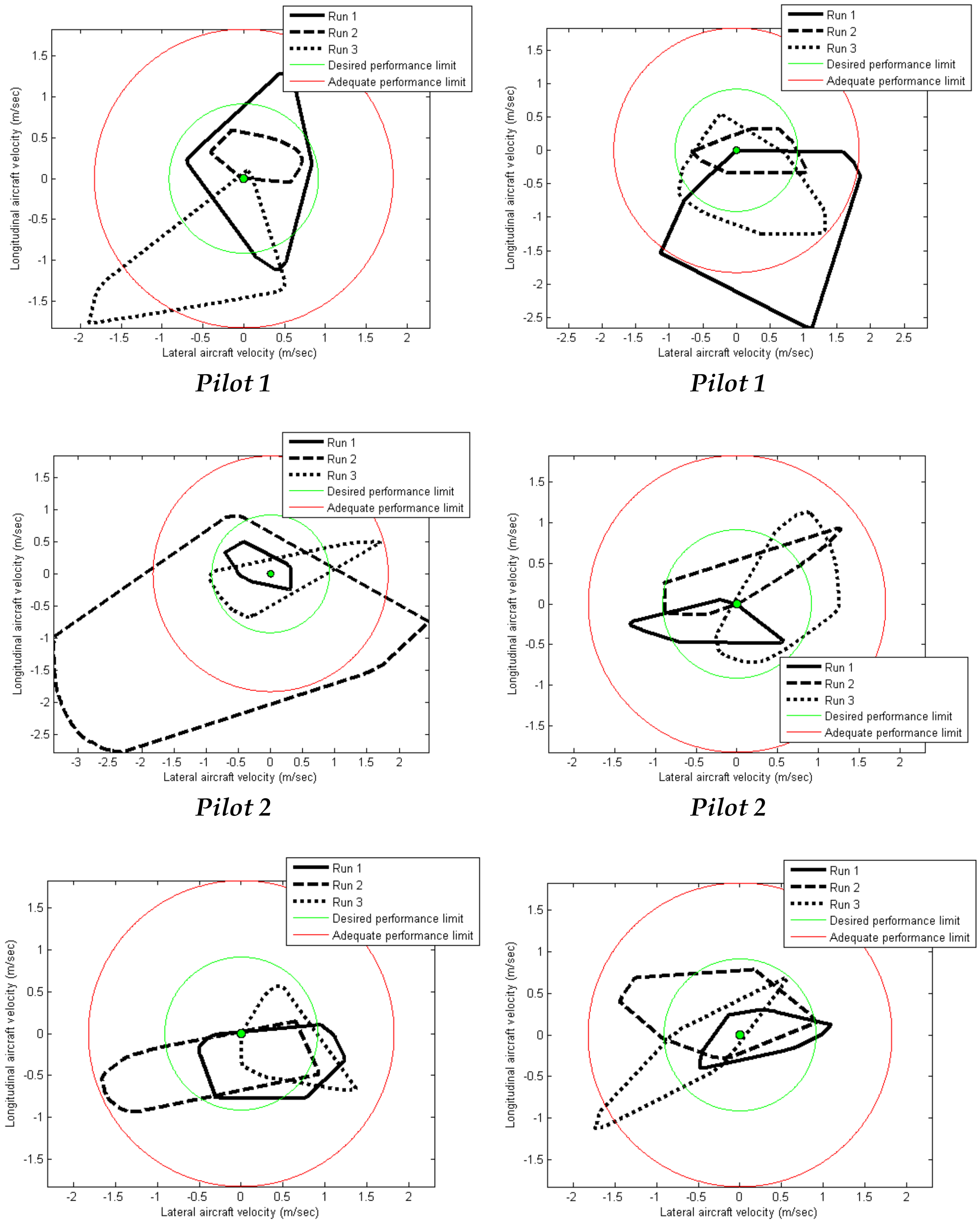

Figure 23 Maximum aircraft drift rate during MH3 using Boresighting and DVR strategies

These results clearly demonstrate the effect of increasing sea state on the ability of pilots to successfully complete the manoeuvre within the limits prescribed. Whilst there is nothing surprising about the fact that significantly adverse conditions make the manoeuvre more difficult, it does show a difference in the efficacy of each reference strategy as the sea state increases. Where the boresighting technique seems more successful in calm seas, the DVR strategy appeared more effective after the introduction of wave motion. Pilots reported that the DVR strategy is taught as preferred reference method, but as the visual references degraded, the boresighting technique was preferred. Although this is not clearly borne out in the results, it is acknowledged that these findings are confined to the simulator environment and may not translate to a flight trial. If the manoeuvre is to be further developed for a flight trial, individual pilot preference for each strategy should be taken into account.

Of the data presented here, there is only one unexpected result. In Figure 23, the drift rate exhibited by Pilot 4 (Run 2) during MH3 using the DVR strategy shows significant deviation when compared to the two other results for the same condition. It is likely that in this scenario the pilot became significantly disoriented, a situation more common in the simulator environment due to the reliance on visual cues. Disorientation generally leads to an increase in PIO, which in turn leads to an increase in the drift rate in both directions (port/starboard). Pilots were generally given the chance to re-attempt the scenario if such a state was entered, in recognition of the fact it was driven by the fidelity of the simulator rather than a true response to the task at hand.

5.2.2 Pilot Feedback

To formally elicit pilot feedback, surveys were administered at the end of each day.

The location of the sun in the scenario initially caused concern as it could be used as a positional cue; however pilots deliberately positioned their aircraft away from the sun. This was consistent with the task operationally, as pilots noted reflections and glare had the potential to distract from the task.

In the highest sea state (MH3) the difficulty of maintaining station using the boresighting method increased notably as the buoy motion became significant. Pilots reported a tendency to 'chase' the buoy movement.

One pilot noted that if altitude maintenance was chosen as their first priority, plan position and heading could not be maintained within limits, and vice-versa.

5.2.3 Additional Testing

A small amount of additional testing was undertaken to address points of interest that arose during the trial. The first to be tested was the inclusion of a graphical rotor downwash model. Although initially included in the scenario, it was removed after pilot feedback indicated it was proving a distraction from the task at hand.

Results of the downwash model inclusion are shown in Figure 24 for a range of sea states and reference strategies. Pilots reported that the inclusion of downwash had little effect on their ability to complete the task despite the fact it improved the fidelity of the fine detail cues.

To assess the effect of altitude, within typical operational values, the maritime hover manoeuvre was repeated at 30 ft for a small number of data points to assess changes to the UCE ratings. No change in UCE was reported by any of the pilots, with feedback indicating it did not have a significant effect on their ability to complete the task.

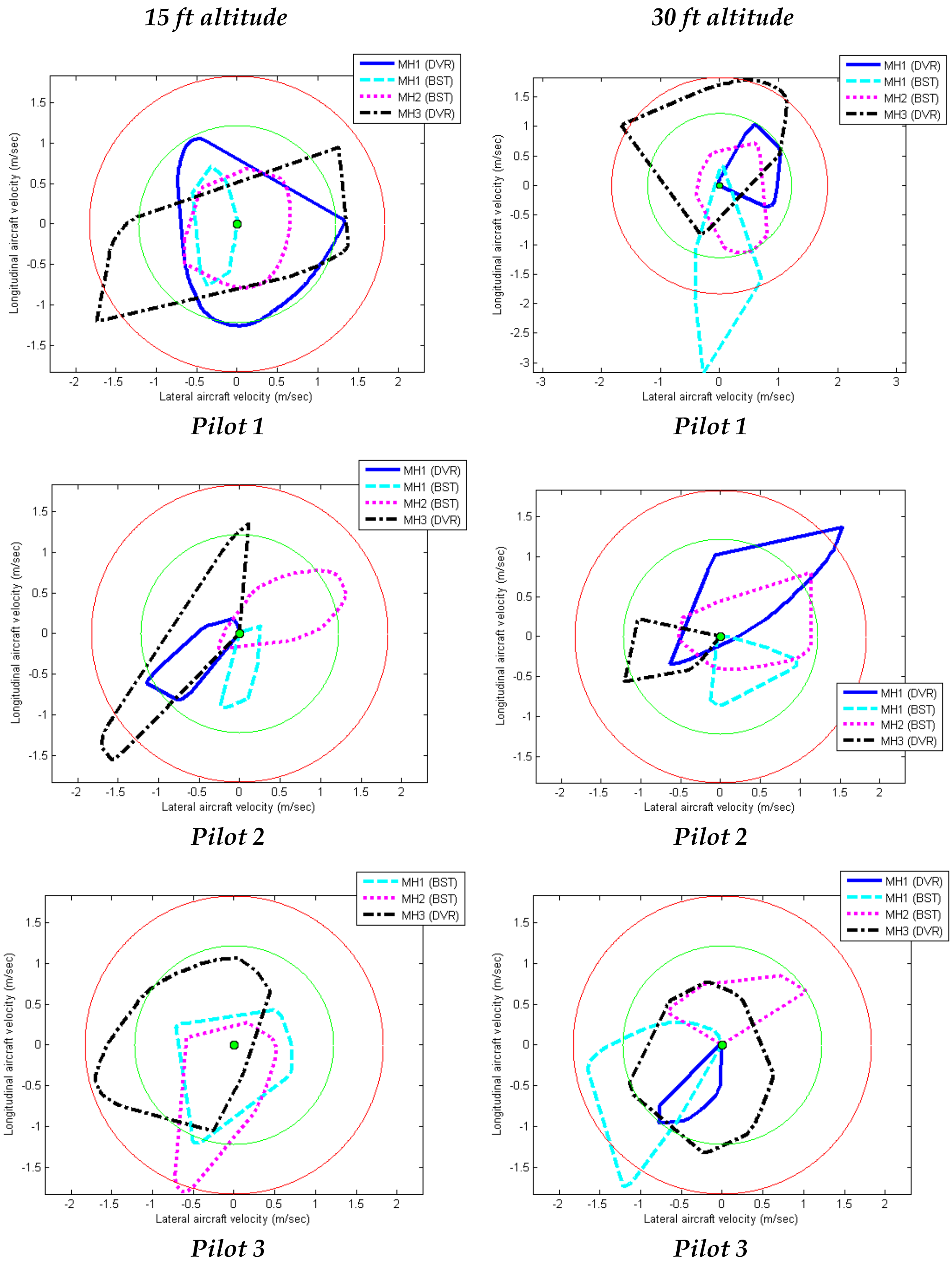

Figure 24 Maximum aircraft drift rate during maritime hover manoeuvre at 15 ft and 30 ft altitude. Rotor wash animation model included in each scenario.

6. Discussion

All pilots provided a significant amount of qualitative feedback during the course of the trial, both during development and as part of the more formal survey process.

6.1 Flight Models

After initial familiarisation with both flight models, it was noted that the workload on the collective for the Squirrel was unrealistically high[14]. The solution taken by pilots was to 'trim out' the collective position. Although a standard technique used in most aircraft, it is not normally possible in the Squirrel, resulting in a non-ideal representation of the aircraft controls. Despite this, pilots noted that the major workload on the Squirrel is in the yaw axis, and that collective workload is generally low.

As expected, pilots had a much greater tendency toward PIO in the Squirrel model when compared to the Seahawk, given the reduced amount of damping inherent in the Squirrel model.

6.2 Simulator Environment

During development of the marker buoy geometry, pilots reported that high detail textures were preferred to high contrast, as this improved the 'realism' of the simulation. This differed from the initial expectation that a high-contrast buoy would provide the best positional cues in the simulated maritime environment.

A major deficiency was also identified in the lack of realistic meteorological conditions. Pilots acknowledged that the inherent complexity of the maritime environment was not easy to simulate, however the absence of realistic wind conditions was conspicuous. Although the wind speed in each scenario matched the sea state, it was simply applied as a force vector on the airframe, which was not appropriately representative of the variability of real world conditions, particularly the lack of wind gusts at higher sea states.

As is noted in the results section, when completing ADS-33 MTEs on the ground course, the simulator environment was feature-rich with sufficiently fine detail to allow pilots to transition between the use of near and far-field cues. As a result, only minor corrections were required to maintain station, significantly reducing the amount of control workload required to complete the task successfully.

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[14] Due to resource constraints, the AS350B Squirrel flight model has only undergone preliminary validation. Pilots indicated that damping in the heave axis should be increased, and this feedback will be incorporated into future development of the model.

6.3 Simulator Task

The largest concern raised by pilots in relation to undertaking the maritime hover manoeuvre task in the simulator was the lack of realistic workload. Workload can be broken down into control workload and cognitive workload. Whilst the control workloads required by each of the flight models were deemed suitable representations of light utility and medium weight cargo helicopters, a significant deficiency was identified in the cognitive workload associated with the maritime hover manoeuvre.

When the control workload is high (i.e. the aircraft is difficult to control) there is little room for cognitive workload. In these situations the primary task becomes maintaining control of the aircraft. In effect, the pilot abandons any attempt to monitor and maintain the aircraft performance with respect to the manoeuvre limits. Conversely, when control workload is low, the primary focus of the pilot is maintaining the aircraft within limits, which results in a high cognitive workload.

For the purposes of this experiment, the control workload was not deemed excessive, yet pilots reported extremely low cognitive workload. The primary cause for the inability to appropriately monitor their performance was inadequate visual cues in the simulator open-ocean environment. Pilots could not identify when the aircraft was approaching the manoeuvre limits and as such were not able to create a cognitive 'feedback loop' which would allow for a realistic cognitive workload.

7. Conclusions

In response to the work undertaken by Manso and Arney [1] a Maritime Hover MTE was assessed for its applicability as a maritime addendum to ADS-33. After initial pilot testing and discussions with AMAFTU, concern was raised over the validity of the task given insufficient cues were available to enable an assessment of the handling qualities of the aircraft. DSTO and AMAFTU agreed that the proposed Maritime Hover MTE would not meet the intent of an ADS-33 manoeuvre; however, the manoeuvre showed promise for its potential to provide an assessment of the effect of changes in the UCE when comparing land-based and open-ocean environments.

To this end, the maritime hover manoeuvre was tested in the AOSC. Several changes were made to the original manoeuvre description. Time on station was reduced from two minutes to 30 seconds, and plan position limits were rates-based rather than position-based. Both these changes were made to reflect the fact the hover was replicating SAR operations, in particular that the aircraft would follow the target as it moved in the water, and not attempt to regain the original position. More than anything else, a stable hover is crucial for SAR operations.

The AOSC experiment results were able to identify the limitations of the current simulator for undertaking manoeuvres in low visual cue environments. Although pilot VCRs identified a clear difference between the ground-based and open-ocean environments, the corresponding UCE ratings did not reflect the difference. The subtleties of the differences in the visual cue environments could not be identified by the ADS-33 UCE rating, noting that a UCE of 3 indicates extremely low visibility environments, such as those requiring the use of night vision devices. These findings confirm that the degradation in visual cues between ground-based operations and the open-ocean environment is not easily quantified.

The major difficulty in assessing a maritime hover manoeuvre in the AOSC simulator was the fact that pilots were severely limited in their ability to complete the task based on the available cues. In the absence of a motion-base only visual cues were available, and it was demonstrated that for precision manoeuvres in open-ocean scenarios, the fidelity of the graphics must be extremely high to realistically represent the task.

Whilst the fidelity of the simulator graphics may not yet be suitable for assessing maritime hover tasks, the AOSC simulator was able to provide the ability to quantify the difference between ground and maritime operating environments when considering visual cues. A clear difference in pilot performance was demonstrated between land-based and open-ocean manoeuvres, and it is this relative difference that may be used to compare results to flight trial data.

8. Recommendations and Future Work

It is the recommendation of this report that neither the Maritime Hover MTE, nor maritime hover manoeuvre be pursued as a viable maritime addendum to ADS-33. Both manoeuvres fail to assess the handling qualities of the rotorcraft; however, there is merit in the potential of the maritime hover manoeuvre to assess the effect of degradation between ground-based and maritime open-ocean operations. Current limitations of the AOSC simulator precluded a full analysis of the maritime hover manoeuvre, and further refinement is required.

The maritime hover manoeuvre is yet to be flown during flight trial to refine manoeuvre limits and enable comparison with the simulator trial. If the manoeuvre were to be formalised to enable more rigorous testing it is recommended that a time to stabilise requirement be included. Similarly to the ADS-33 ground course hover manoeuvre, a multi-axis arrival over the hover point should be included in the maritime hover manoeuvre. Unlike the ground hover MTE; it is recommended that the maritime hover manoeuvre implement two sets of limits for each phase of the manoeuvre. The time to stabilise phase should have the same limits applied as for the ground hover, and once hover is established, the rates-based limits applied.

9. Acknowledgements

The authors would like to acknowledge and sincerely thank the four pilots who took part in this study. Thanks to LCDR David Ostler for undertaking the initial testing, and for both their support and participation in the final trials, thanks to LCDR Kimble Taylor, LCDR Michael Waddell and LCDR Andrew Rohrsheim.

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Appendix A: Ground Hover MTE as per ADS-33E-PRF

a. Objectives.

- Check ability to transition from translating flight to a stabilized hover with precision and a reasonable amount of aggressiveness.
- Check ability to maintain precise position, heading, and altitude in the presence of a moderate wind from the most critical direction in the GVE; and with calm winds allowed in the DVE.

b. Description of manoeuvre.
Initiate the manoeuvre at a ground speed of between 6 and 10 knots, at an altitude less than 20 ft. For rotorcraft carrying external loads, the altitude will have to be adjusted to provide a 10 ft load clearance. The target hover point shall be oriented approximately 45 degrees relative to the heading of the rotorcraft. The target hover point is a repeatable, ground-referenced point from which rotorcraft deviations are measured. The ground track should be such that the rotorcraft will arrive over the target hover point (see illustration in Figure 24). In the GVE, the manoeuvre shall be accomplished in calm winds and in moderate winds from the most critical direction. If a critical direction has not been defined, the hover shall be accomplished with the wind blowing directly from the rear of the rotorcraft.

c. Description of test course.
The suggested test course for this manoeuvre is shown in Figure 24 *(included overleaf)*. Note that the hover altitude depends on the height of the hover sight and the distance between the sight, the hover target, and the rotorcraft. These dimensions may be adjusted to achieve a desired hover altitude.

d. Performance standards.
Accomplish the transition to hover in one smooth manoeuvre. It is not acceptable to accomplish most of the deceleration well before the hover point and then to creep up to the final position.

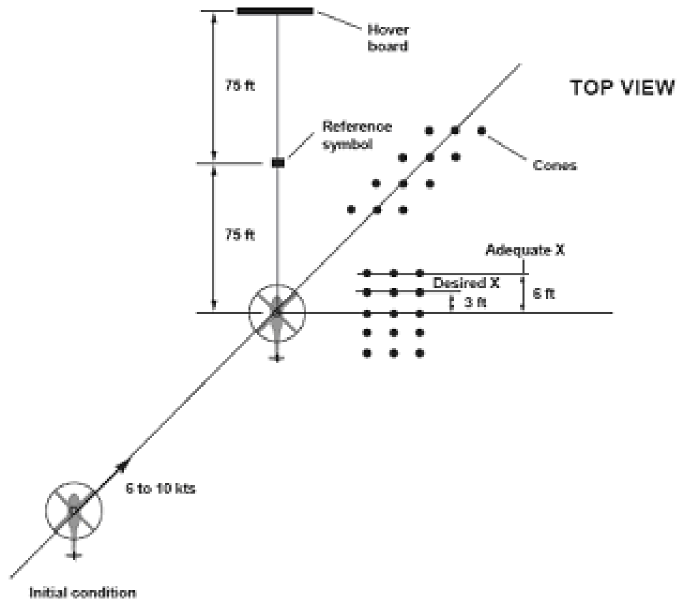
Performance – Hover

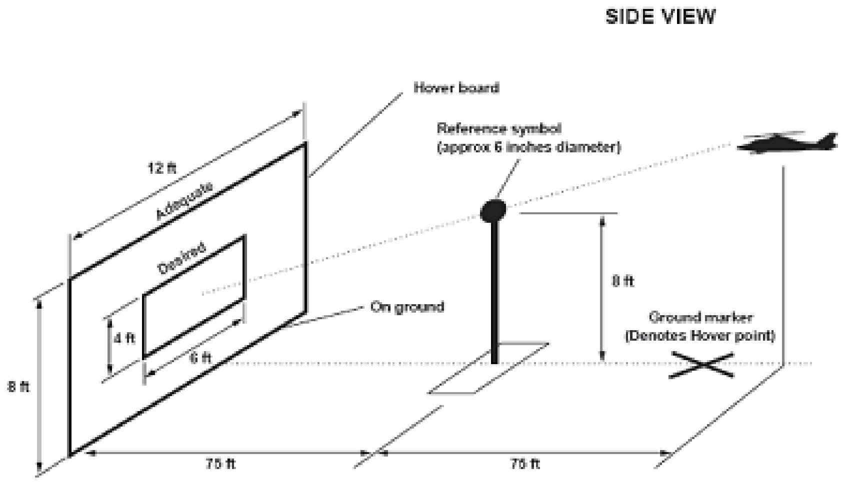
	Scout/Attack GVE	Scout/Attack DVE	Cargo/Utility GVE	Cargo/Utility DVE	Externally Slung Load GVE	Externally Slung Load DVE
DESIRED PERFORMANCE						
• Attain a stabilized hover within X seconds of initiation of deceleration:	3 sec	10 sec	5 sec	10 sec	10 sec	13 sec
• Maintain a stabilized hover for at least:	30 sec	30 sec	30 sec	30 sec	30 sec	30 sec
• Maintain the longitudinal and lateral position within ±X ft of a point on the ground:	3 ft	3 ft	3 ft	3 ft	3 ft	3 ft
• Maintain altitude within ±X ft:	2 ft	2 ft	2 ft	2 ft	4 ft	4 ft
• Maintain heading within ±X deg:	5 deg	5 deg	5 deg	5 deg	5 deg	5 deg
• There shall be no objectionable oscillations in any axis either during the transition to hover or the stabilized hover	✓	✓	✓	✓	✓	N/A*

*Note: For all tables, ✓= performance standard applies; NA = performance standard not applicable

	Scout/Attack GVE	Scout/Attack DVE	Cargo/Utility GVE	Cargo/Utility DVE	Externally Slung Load GVE	Externally Slung Load DVE
ADEQUATE PERFORMANCE						
• Attain a stabilized hover within X seconds of initiation of deceleration:	8 sec	20 sec	8 sec	15 sec	15 sec	18 sec
• Maintain a stabilized hover for at least:	30 sec	30 sec	30 sec	30 sec	30 sec	30 sec
• Maintain the longitudinal and lateral position within ±X ft of a point on the ground:	6 ft	8 ft	6 ft	6 ft	6 ft	6 ft
• Maintain altitude within ±X ft:	4 ft	4 ft	4 ft	4 ft	6 ft	6 ft
• Maintain heading within ±X deg:	10deg	10 deg	10 deg	10 deg	10 deg	10 deg

Suggested course for hover manoeuvre:



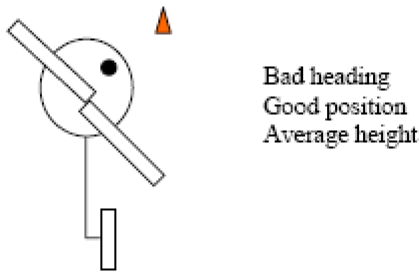


Appendix B: Maritime Hover Reference Strategies

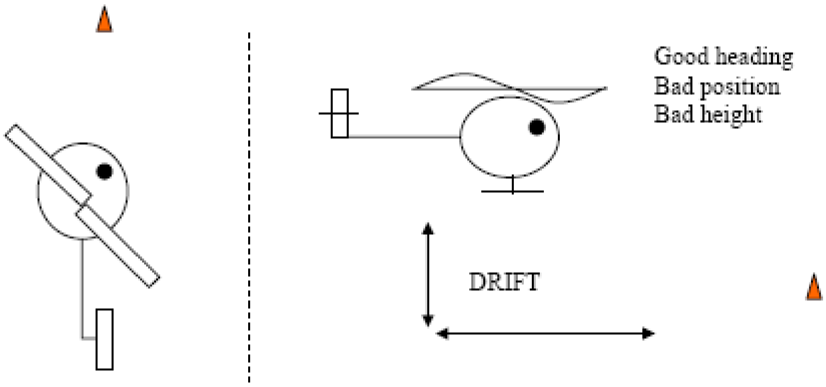
Taken from DSTO-TN-0936

Strategies employed

- The diagonal visual reference strategy showed no appreciable deterioration in position and height maintenance performance when compared to the baseline manoeuvre (<=1 HQR difference). However the heading maintenance deteriorated by 2 HQRs.



- The boresighting visual reference strategy presented no change in heading maintenance performance when compared to the baseline manoeuvre. However there were appreciable differences in height and longitudinal position maintenance due to drift.



Appendix C: Pirouette MTE as per ADS-33E-PRF

Pirouette

a. Objectives.

- Check ability to accomplish precision control of the rotorcraft simultaneously in the pitch, roll, yaw, and heave axes.
- In the GVE, check ability to control the rotorcraft precisely in a moderate wind that is continuously varying in direction relative to the rotorcraft heading.
- In the DVE, check for degraded display symbology and dynamics during multiple axis manoeuvring.

b. Description of manoeuvre.
Initiate the manoeuvre from a stabilized hover over a point on the circumference of a 100 ft radius circle with the nose of the rotorcraft pointed at a reference point at the centre of the circle, and at a hover altitude of approximately 10 ft. Accomplish a lateral translation around the circle, keeping the nose of rotorcraft pointed at the centre of the circle, and the circumference of the circle under a selected point on the rotorcraft. Maintain essentially constant lateral groundspeed throughout the lateral translation (note: nominal lateral velocity will be approximately 8 knots for the 45-sec and 6 knots for the 60-sec time around the circle). Terminate the manoeuvre with a stabilized hover over the starting point. Perform the manoeuvre in both directions. In the GVE, the manoeuvre shall be accomplished in calm winds and in moderate winds from the most critical direction at the starting point.

c. Description of test course.
The test course shall consist of markings on the ground that clearly denote the circular pathways that define desired and adequate performance. The suggested course shown in Figure 25 *(shown overleaf)* is considered adequate for the evaluation. It may also be useful to add objects to assist the pilot with vertical cueing, such as a post at the centre of the circle.

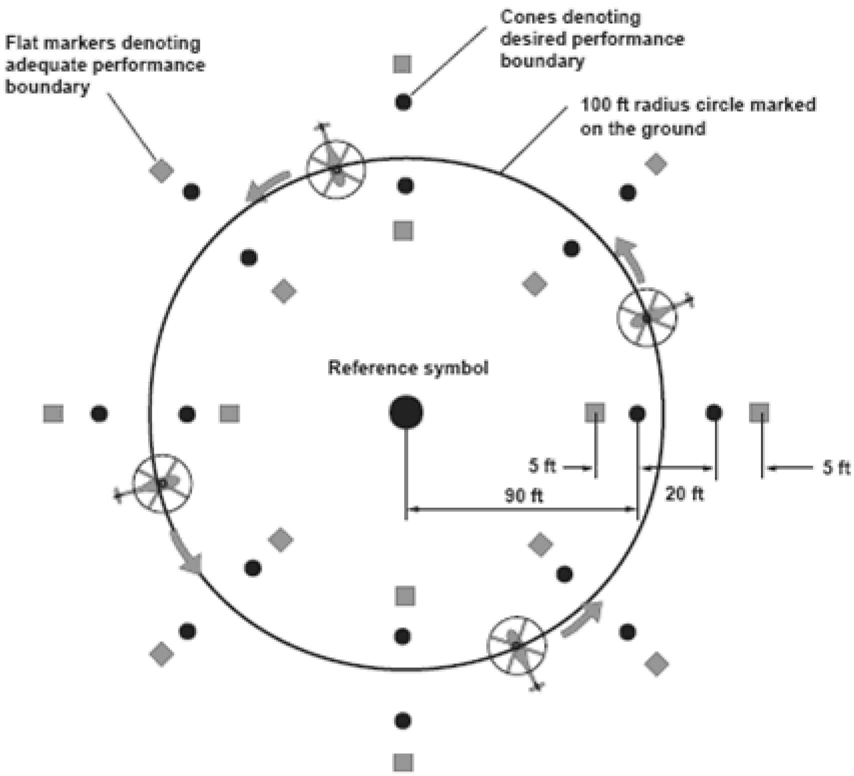
d. Performance standards.

Performance – Pirouette

	GVE	DVE
DESIRED PERFORMANCE		
• Maintain a selected reference point on the rotorcraft within ±X ft of the circumference of the circle.	10 ft	10 ft
• Maintain altitude within ±X ft:	3 ft	4 ft
• Maintain heading so that the nose of the rotorcraft points at the centre of the circle within ±X deg:	10 deg	10 deg
• Complete the circle and arrive back over the starting point within:	45 sec	60 sec
• Achieve a stabilized hover (within desired hover reference point) within X seconds after returning to the starting point.	5 sec	10 sec
• Maintain the stabilized hover for X sec	5 sec	5 sec

	GVE	DVE
ADEQUATE PERFORMANCE		
• Maintain a selected reference point on the rotorcraft within ±X ft of the circumference of the circle.	15 ft	15 ft
• Maintain altitude within ±X ft:	10 ft	10 ft
• Maintain heading so that the nose of the rotorcraft points at the centre of the circle within ±X deg:	15 deg	15 deg
• Complete the circle and arrive back over the starting point within:	60 sec	75 sec
• Achieve a stabilized hover (within desired hover reference point) within X seconds after returning to the starting point.	10 sec	20 sec
• Maintain the stabilized hover for X sec	5 sec	5 sec

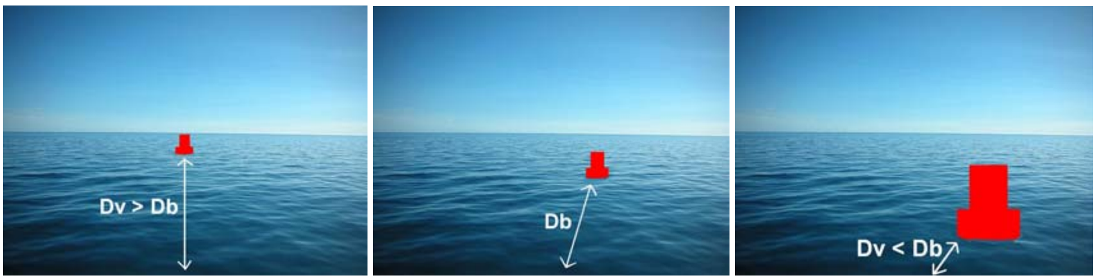
Suggested course for pirouette manoeuvre:



Appendix D: Data Point Information for the Visual Perception Threshold Experiment

Data Point	D_v (m)	$D_b - D_v$ (m)	Correct Response
1	0	50	Closer
2	25	25	Closer
3	37.5	12.5	Closer
4	43.65	6.25	Closer
5	46.87	3.13	Closer
6	48.44	1.56	Closer
7	49.22	0.78	Closer
8	49.61	0.39	Closer
9	49.81	0.19	Closer
10	50.19	-0.19	Farther
11	50.39	-0.39	Farther
12	50.78	-0.78	Farther
13	51.56	-1.56	Farther
14	53.13	-3.13	Farther
15	56.25	-6.25	Farther
16	62.5	-12.5	Farther
17	75	-25	Farther
18	100	-50	Farther

Out-the-window views of buoys in $D_v > D_b$ ('farther'), D_b (baseline) and $D_v < D_b$ ('closer') positions respectively:



Appendix E: Maximum Deviation during Manoeuvre, AS350B Squirrel Flight Model

E.1 ADS-33 Ground Hover

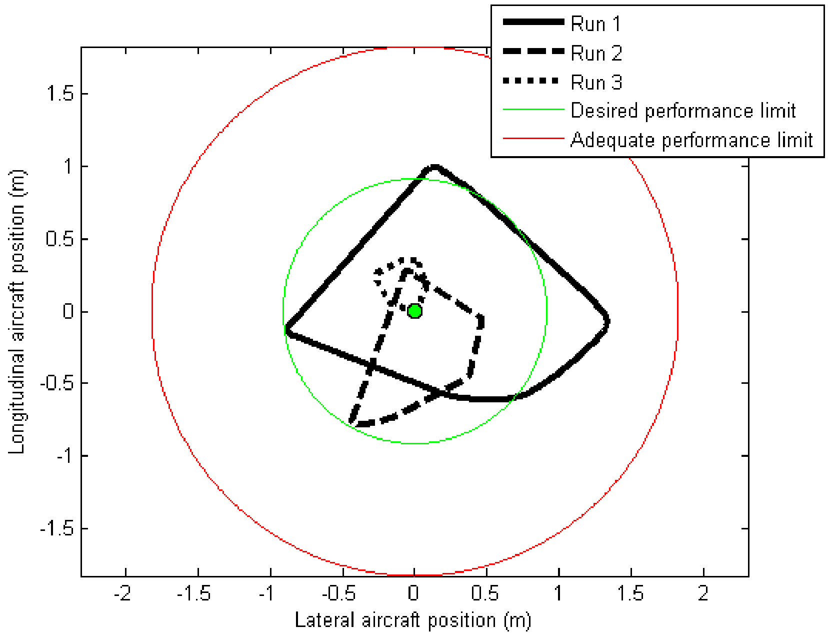


Figure 25 Maximum deviation of aircraft plan position during ADS-33 Ground Hover Manoeuvre, Pilot 2

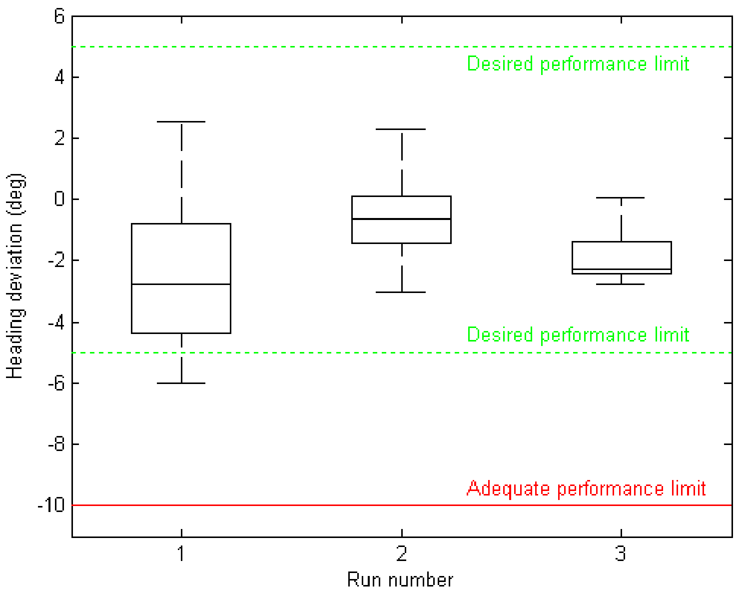


Figure 26 Maximum deviation of aircraft heading during ADS-33 Ground Hover Manoeuvre, Pilot 2

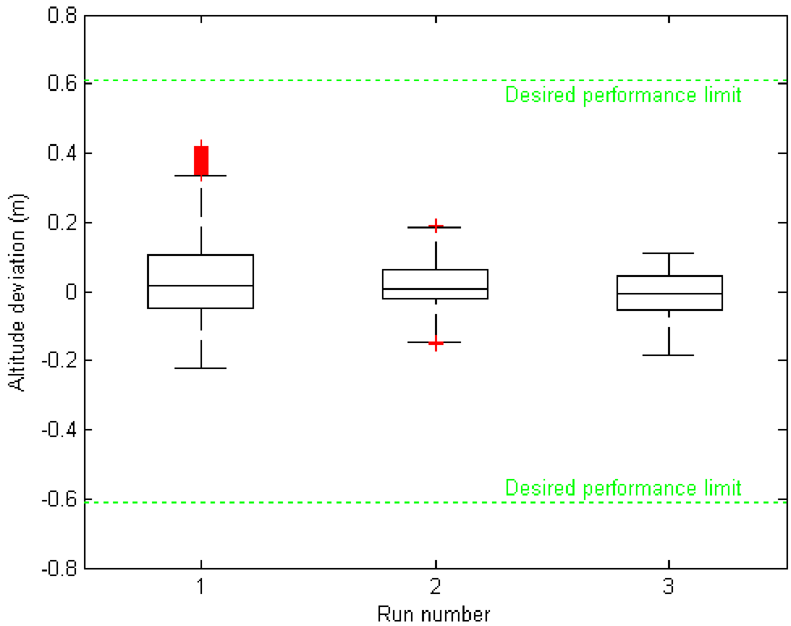


Figure 27 Maximum deviation of aircraft altitude during ADS-33 Ground Hover Manoeuvre, Pilot 2

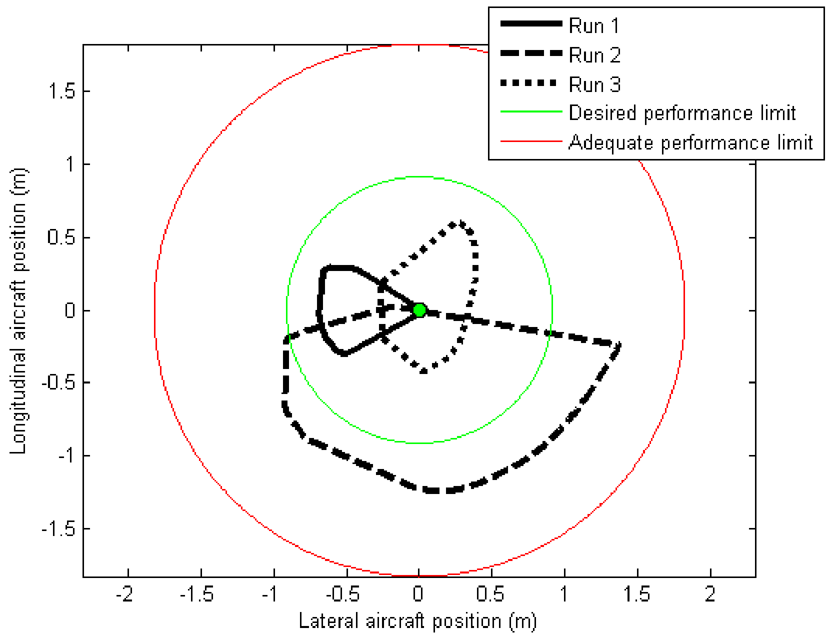


Figure 28 Maximum deviation of aircraft plan position during ADS-33 Ground Hover Manoeuvre, Pilot 3

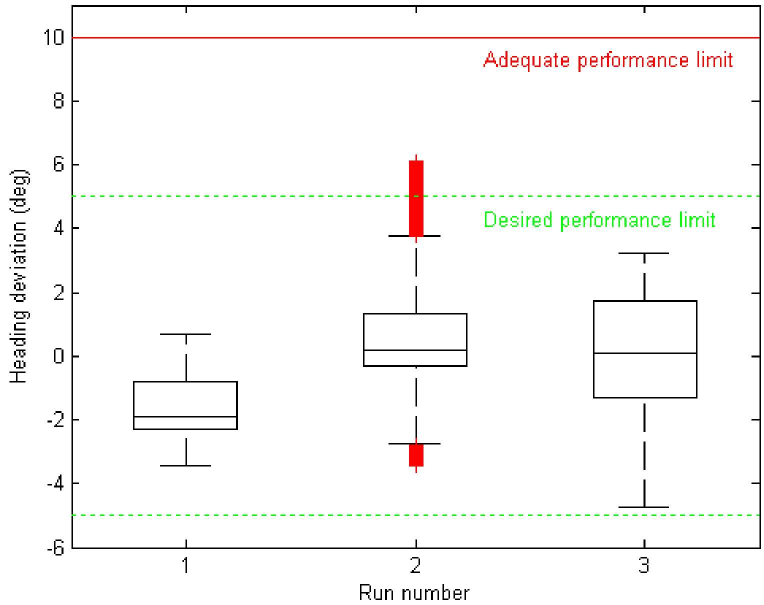


Figure 29 Maximum deviation of aircraft heading during ADS-33 Ground Hover Manoeuvre, Pilot 3

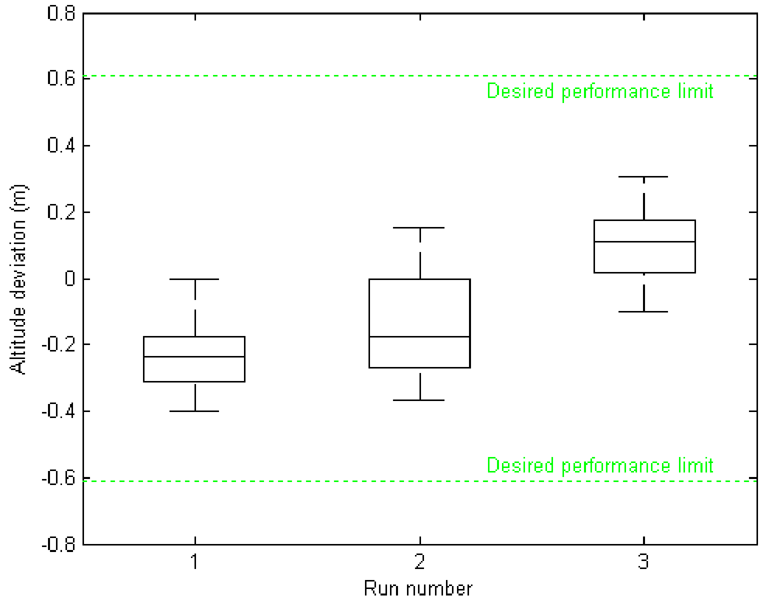


Figure 30 Maximum deviation of aircraft altitude during ADS-33 Ground Hover Manoeuvre, Pilot 3

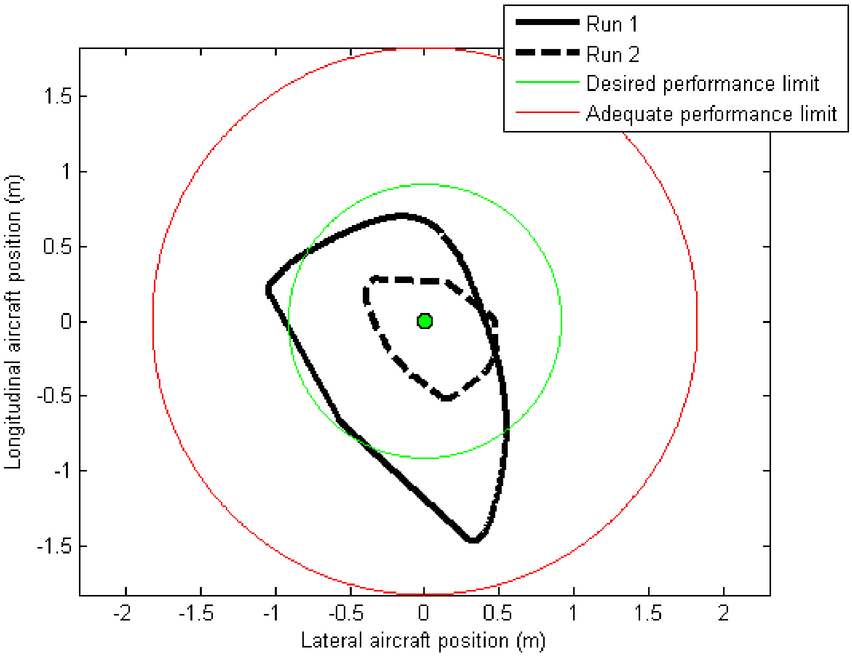


Figure 31 Maximum deviation of aircraft plan position during ADS-33 Ground Hover Manoeuvre, Pilot 4

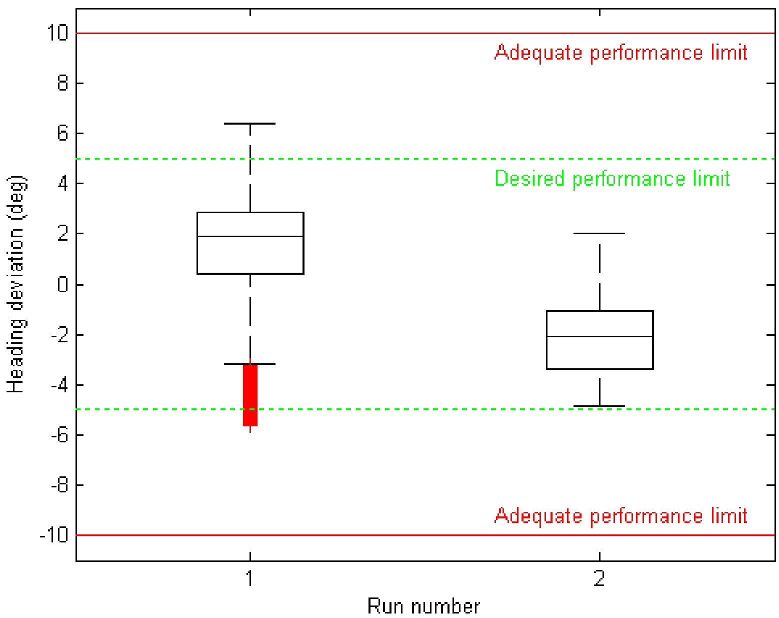


Figure 32 Maximum deviation of aircraft heading during ADS-33 Ground Hover Manoeuvre, Pilot 4

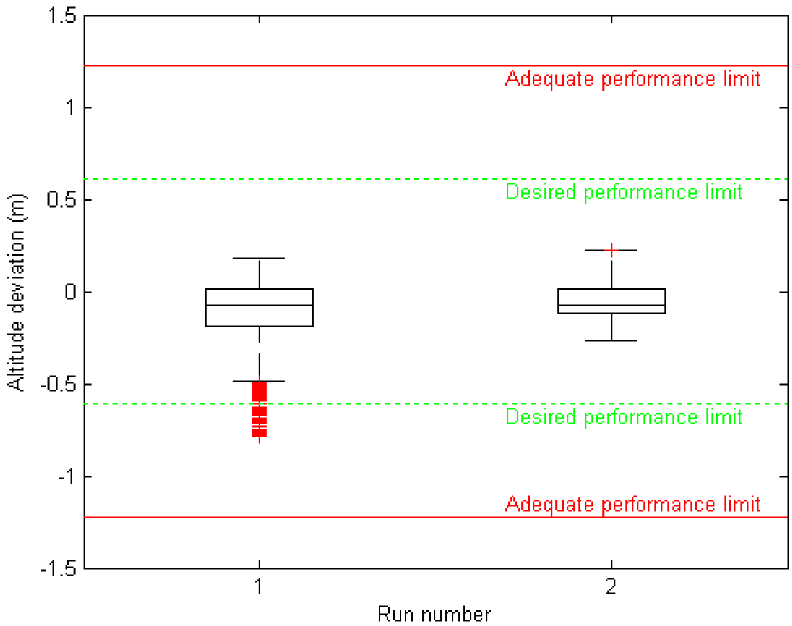


Figure 33 Maximum deviation of aircraft altitude during ADS-33 Ground Hover Manoeuvre, Pilot 4

E.2 ADS-33 Pirouette

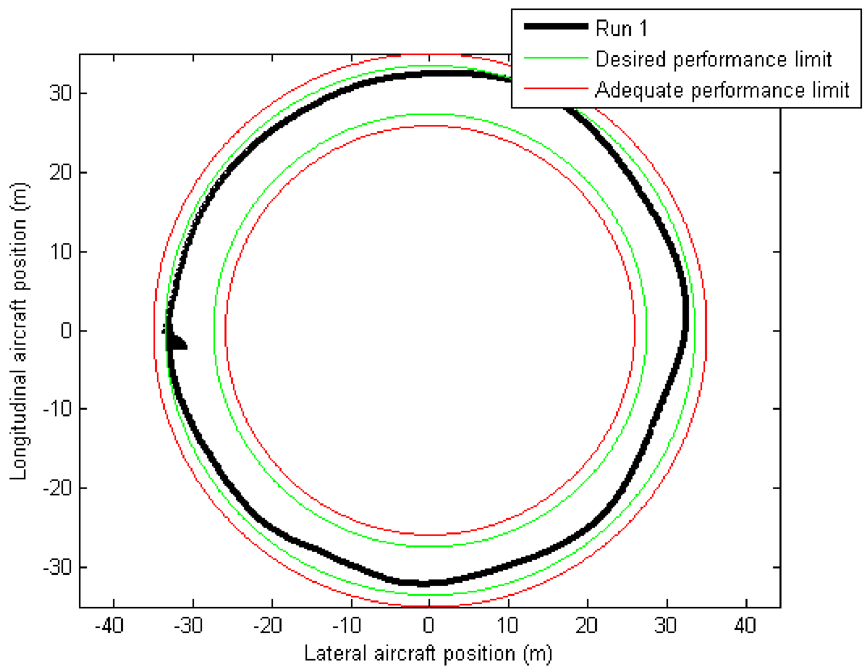


Figure 34 Maximum deviation of aircraft plan position during ADS-33 Pirouette Manoeuvre, Pilot 2, Run 1

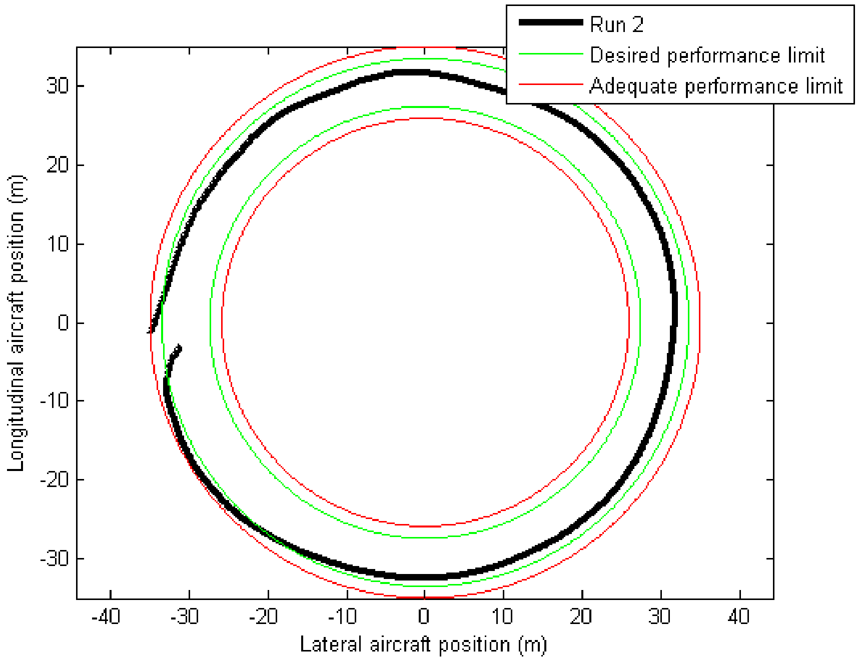


Figure 35 Maximum deviation of aircraft plan position during ADS-33 Pirouette Manoeuvre, Pilot 2, Run 2

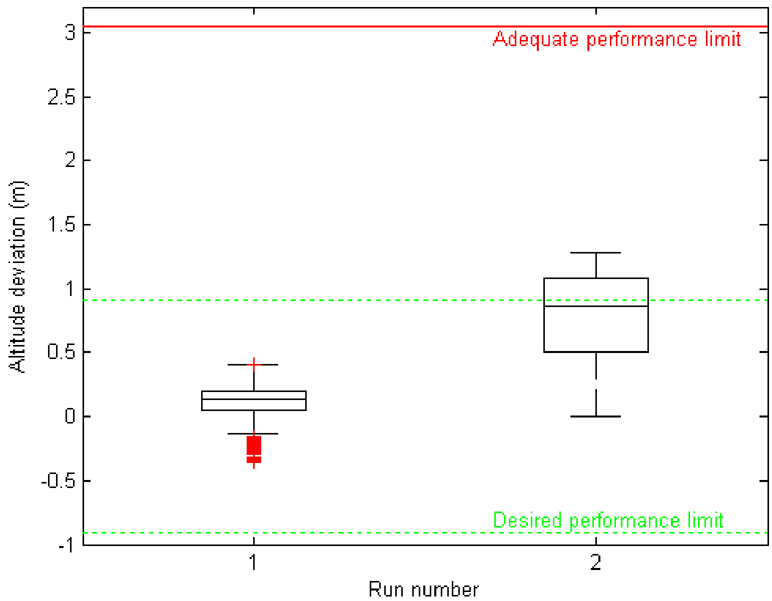


Figure 36 Maximum deviation of aircraft altitude during ADS-33 Pirouette Manoeuvre, Pilot 2

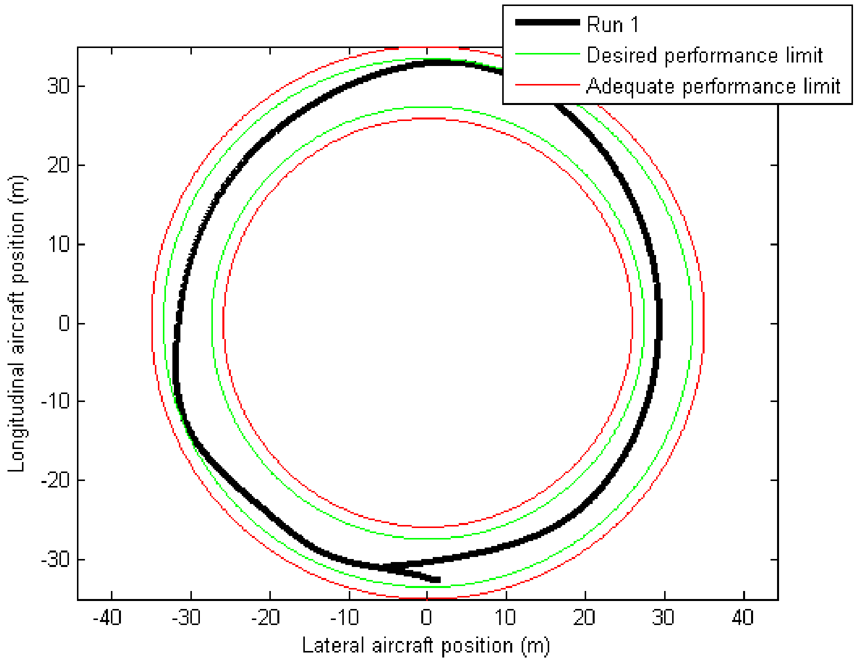


Figure 37 Maximum deviation of aircraft plan position during ADS-33 Pirouette Manoeuvre, Pilot 3, Run 1

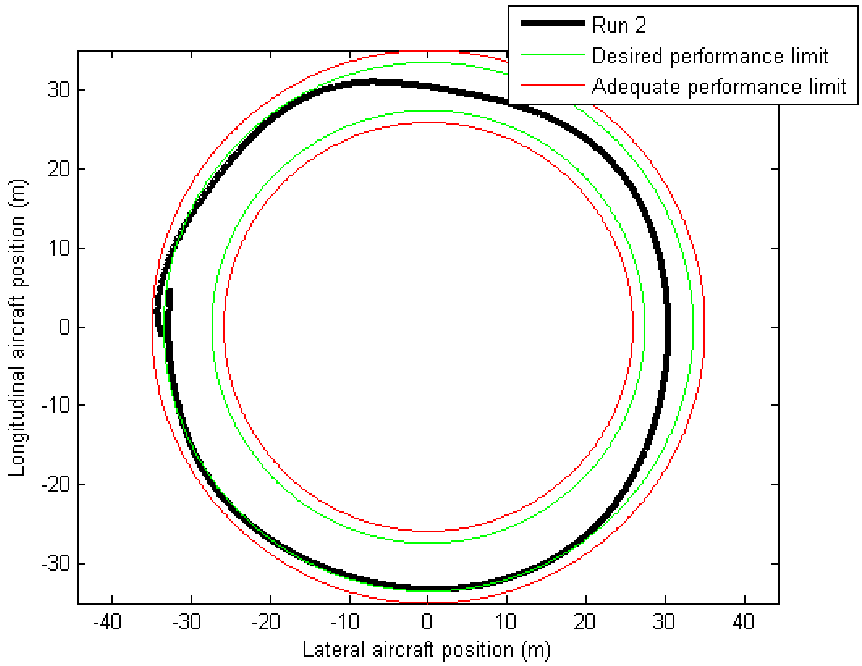


Figure 38 Maximum deviation of aircraft plan position during ADS-33 Pirouette Manoeuvre, Pilot 3, Run 2

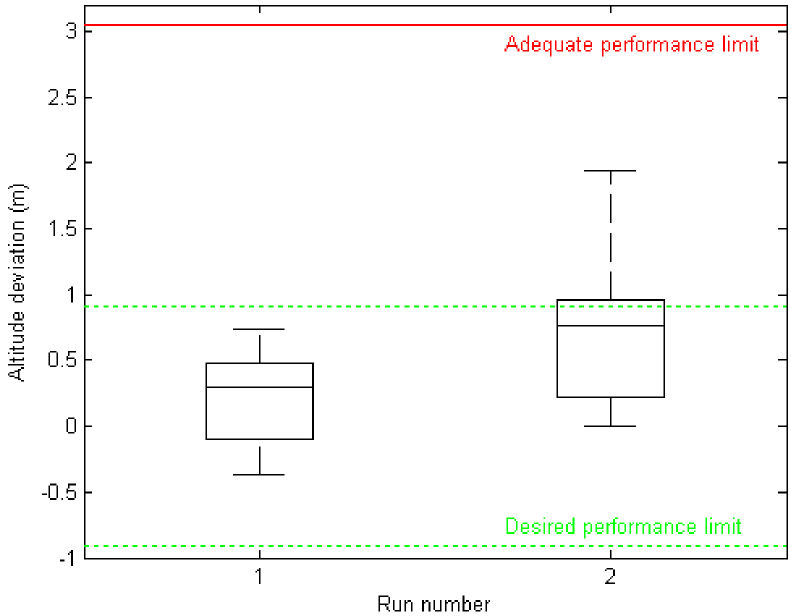


Figure 39 *Maximum deviation of aircraft altitude during ADS-33 Ground Pirouette Manoeuvre, Pilot 3*

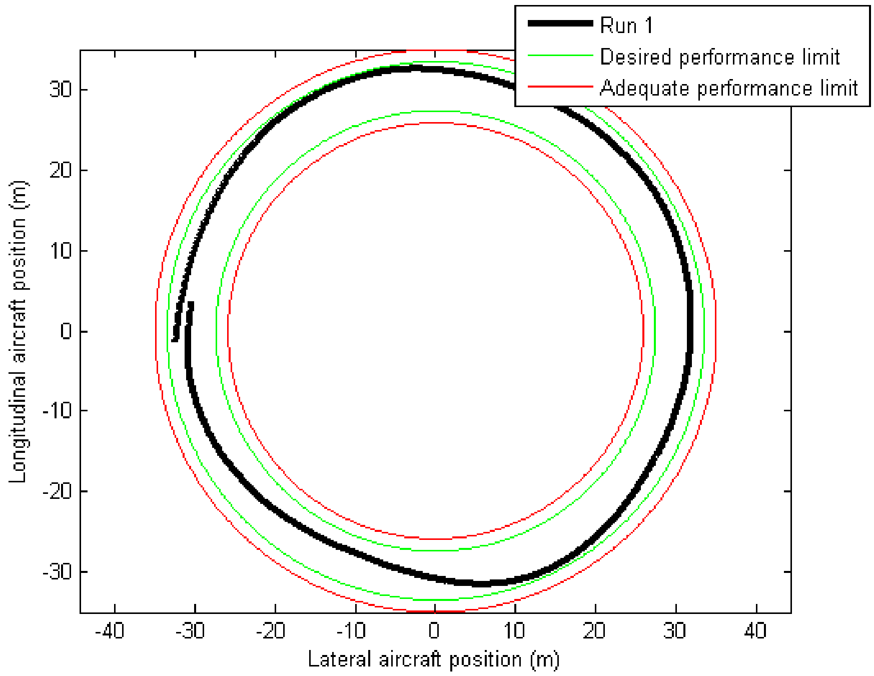


Figure 40 *Maximum deviation of aircraft plan position during ADS-33 Pirouette Manoeuvre, Pilot 4, Run 1*

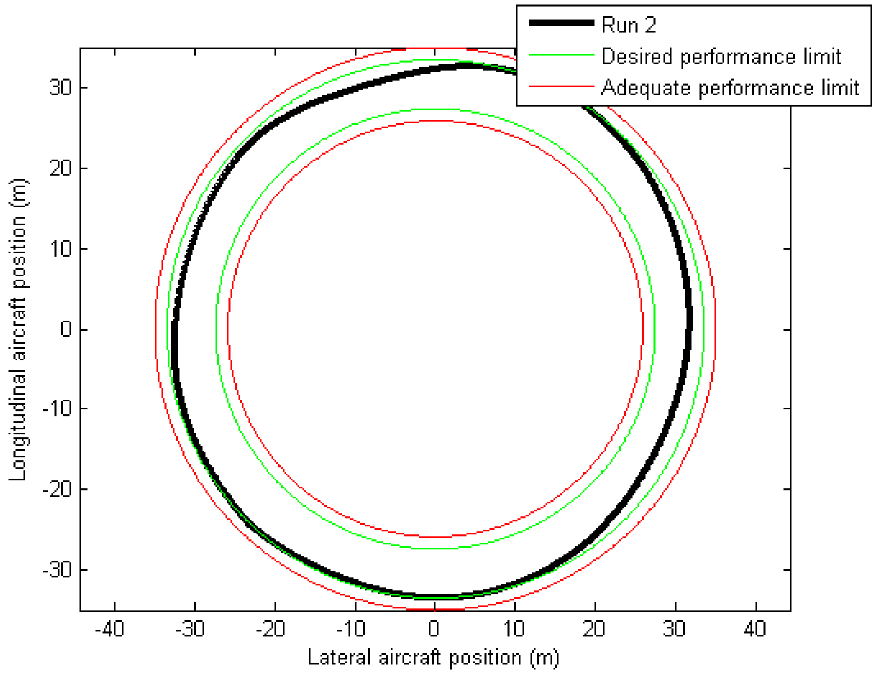


Figure 41 Maximum deviation of aircraft plan position during ADS-33 Pirouette Manoeuvre, Pilot 4, Run 2

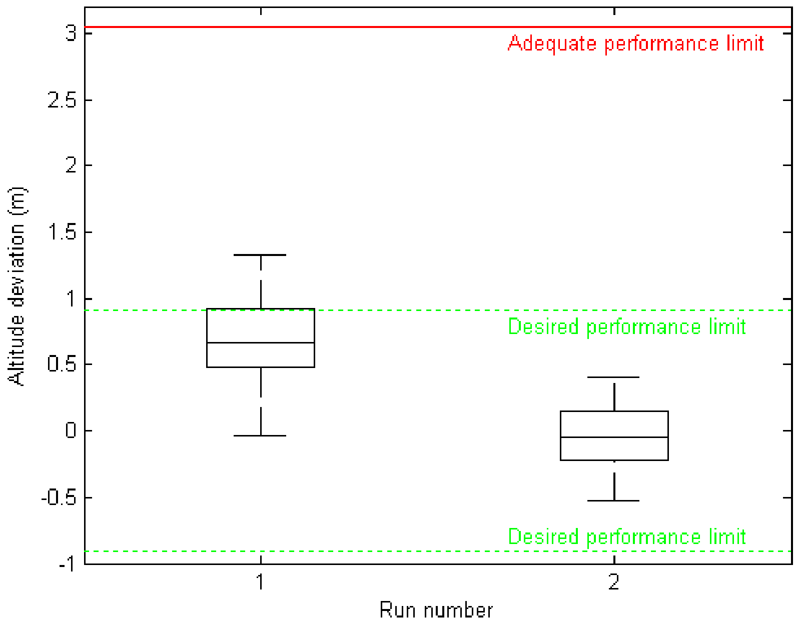


Figure 42 Maximum deviation of aircraft altitude during ADS-33 Ground Pirouette Manoeuvre, Pilot 4

E.3 Maritime Hover Manoeuvre, Calm Seas (MH1)

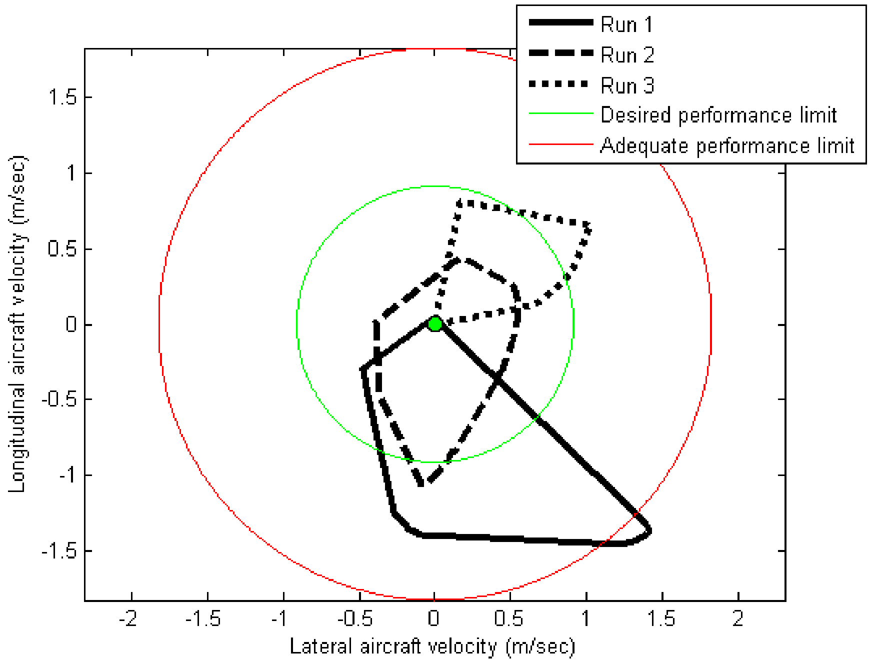


Figure 43 Maximum aircraft drift rate during MH1 using DVR strategy, Pilot 2

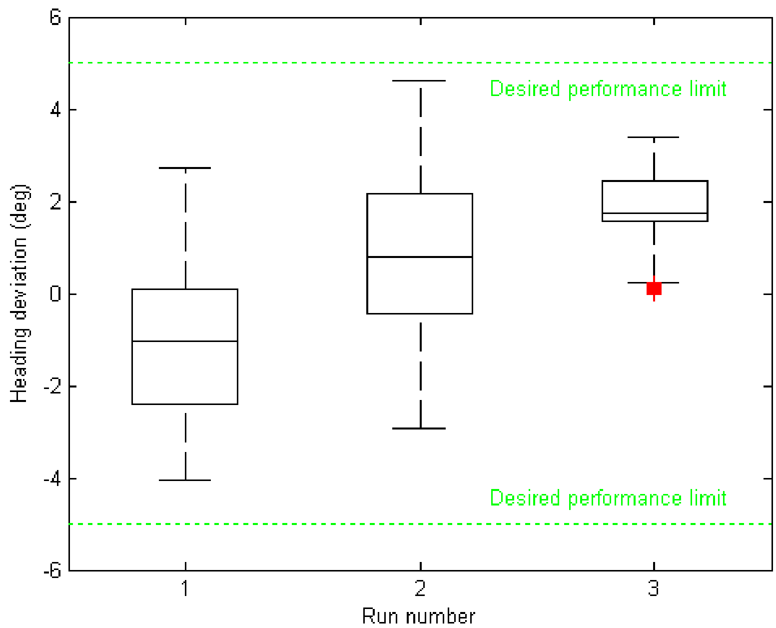


Figure 44 Maximum deviation of aircraft heading during MH1 using DVR strategy, Pilot 2

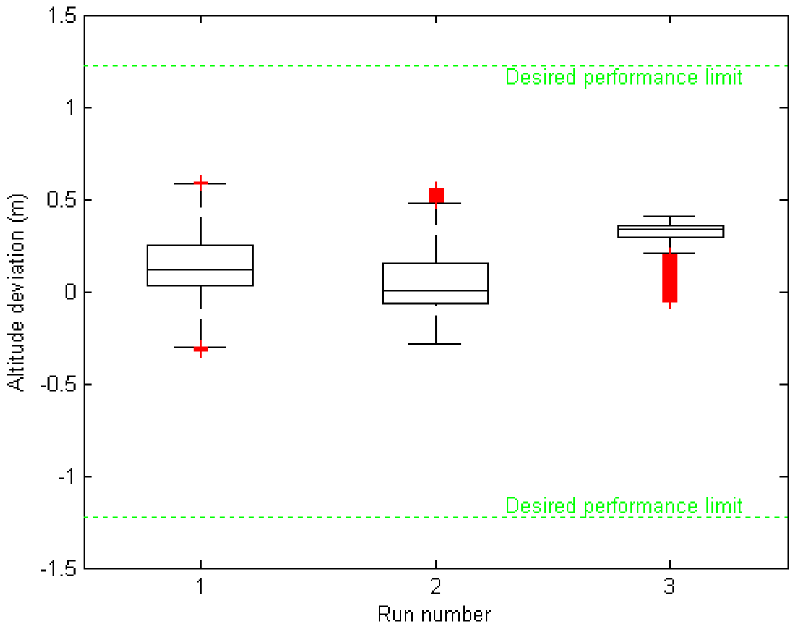


Figure 45 Maximum deviation of aircraft altitude during MH1 using DVR strategy, Pilot 2

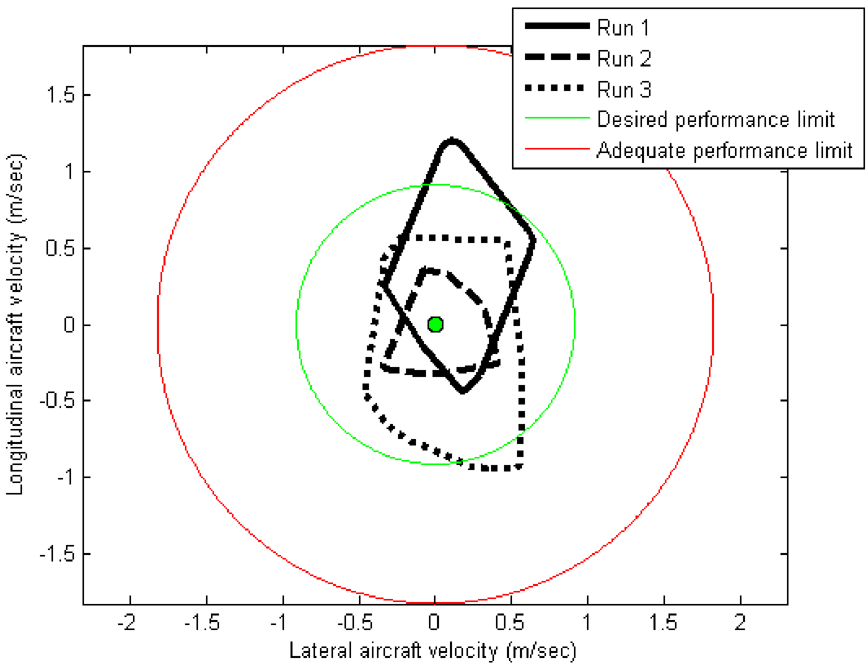


Figure 46 Maximum aircraft drift rate during MH1 using Boresighting reference strategy, Pilot 2

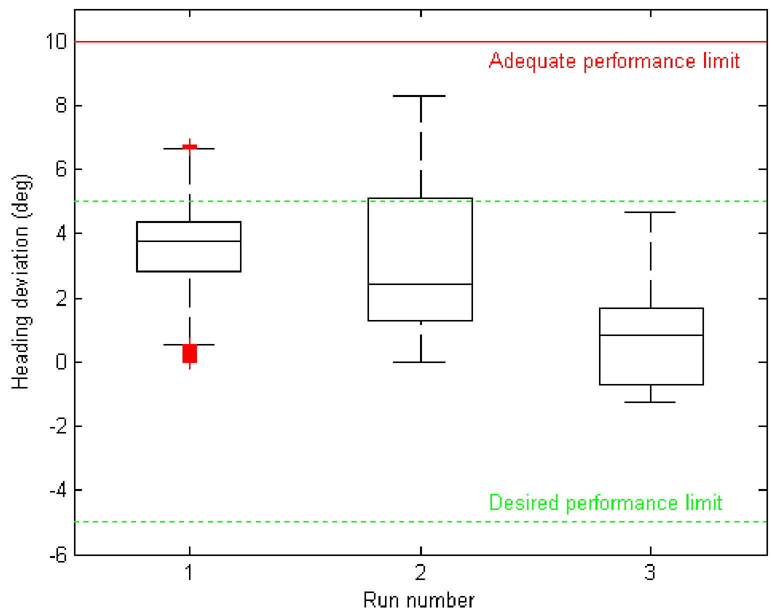


Figure 47 Maximum deviation of aircraft heading during MH1 using Boresighting reference strategy, Pilot 2

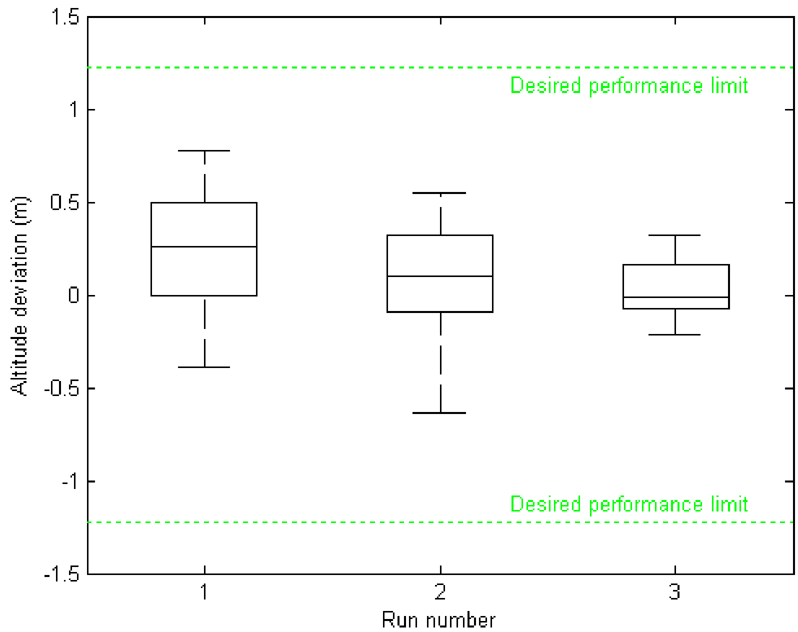


Figure 48 Maximum deviation of aircraft altitude during MH1 using Boresighting reference strategy, Pilot 2

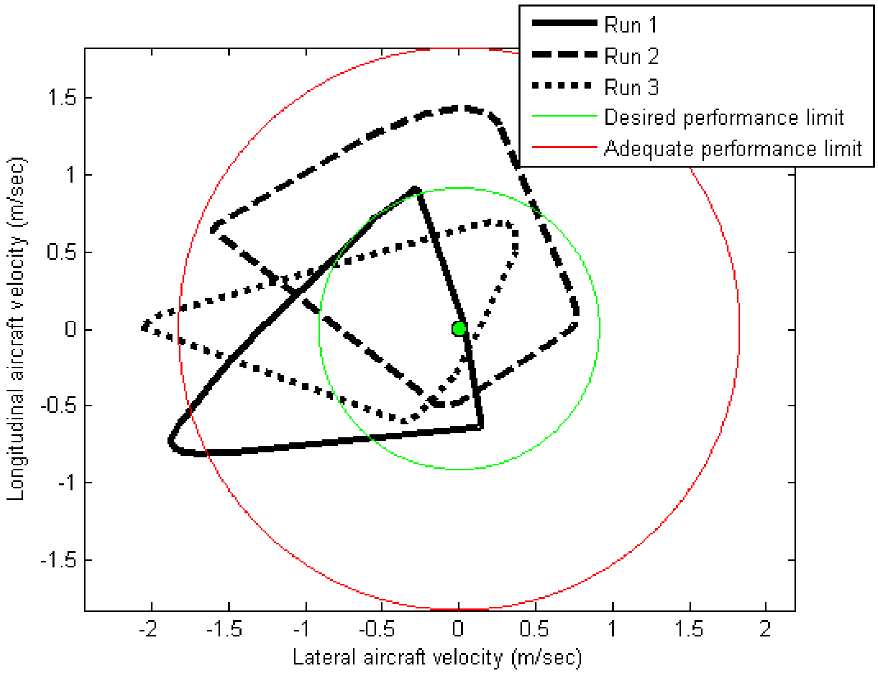


Figure 49 Maximum aircraft drift rate during MH1 using DVR strategy, Pilot 3

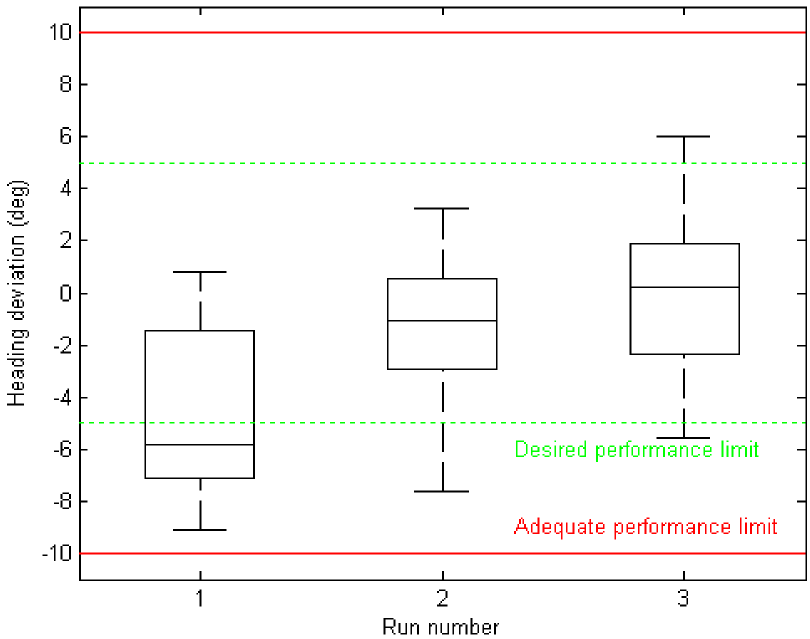


Figure 50 Maximum deviation of aircraft heading during MH1 using DVR strategy, Pilot 3

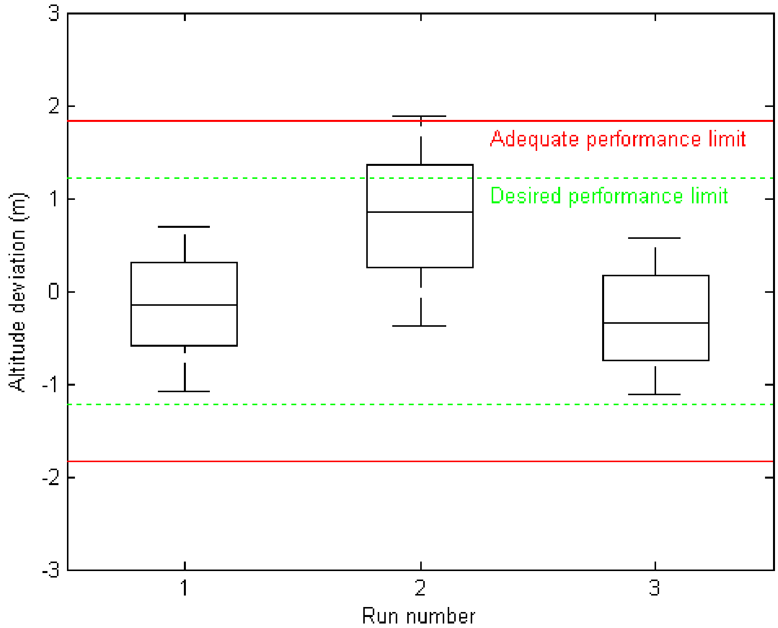


Figure 51 Maximum deviation of aircraft altitude during MH1 using DVR strategy, Pilot 3

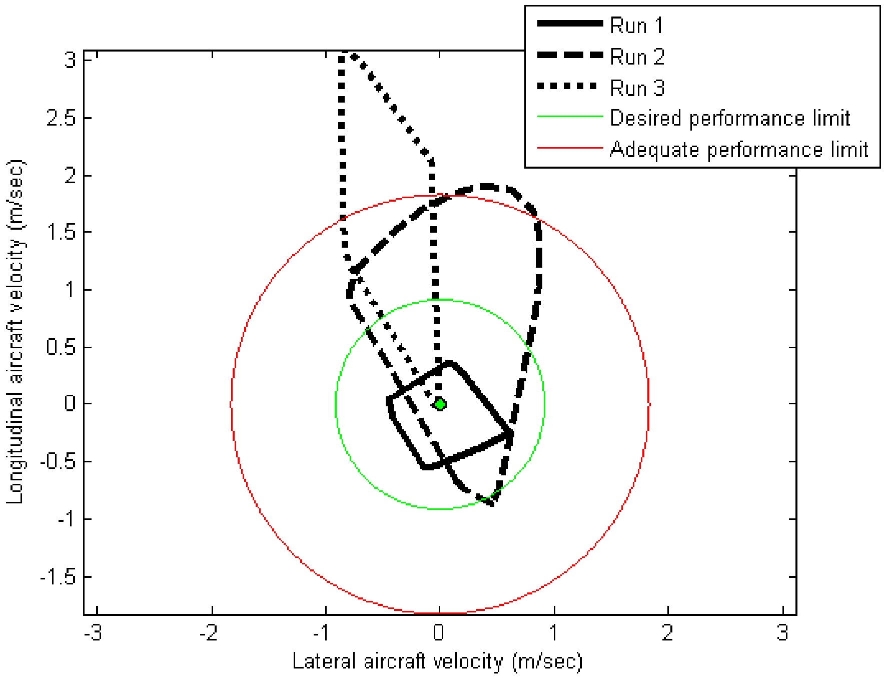


Figure 52 Maximum aircraft drift rate during MH1 using Boresighting reference strategy, Pilot 3

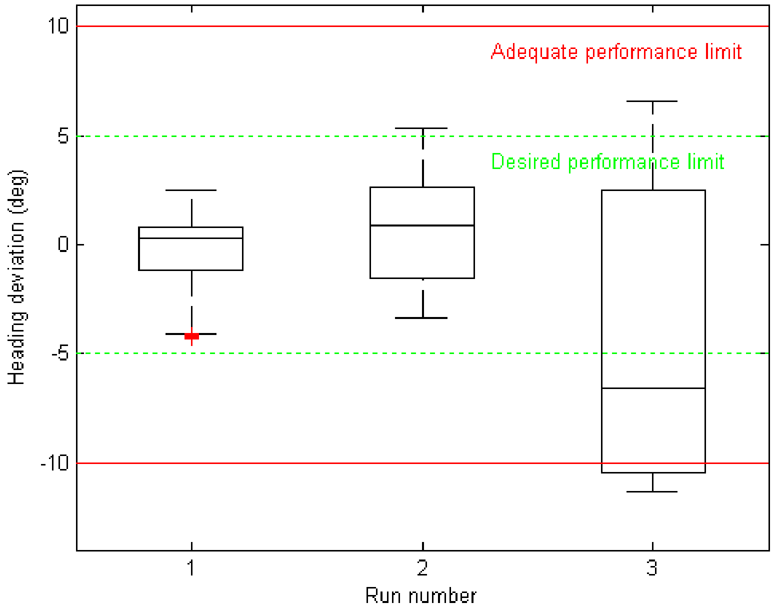


Figure 53 Maximum deviation of aircraft heading during MH1 using Boresighting reference strategy, Pilot 3

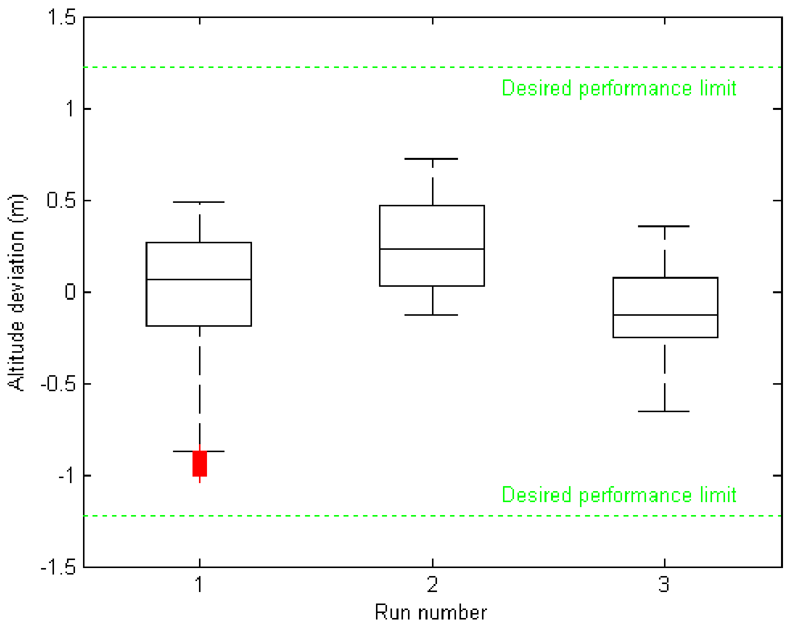


Figure 54 Maximum deviation of aircraft altitude during MH1 using Boresighting reference strategy, Pilot 3

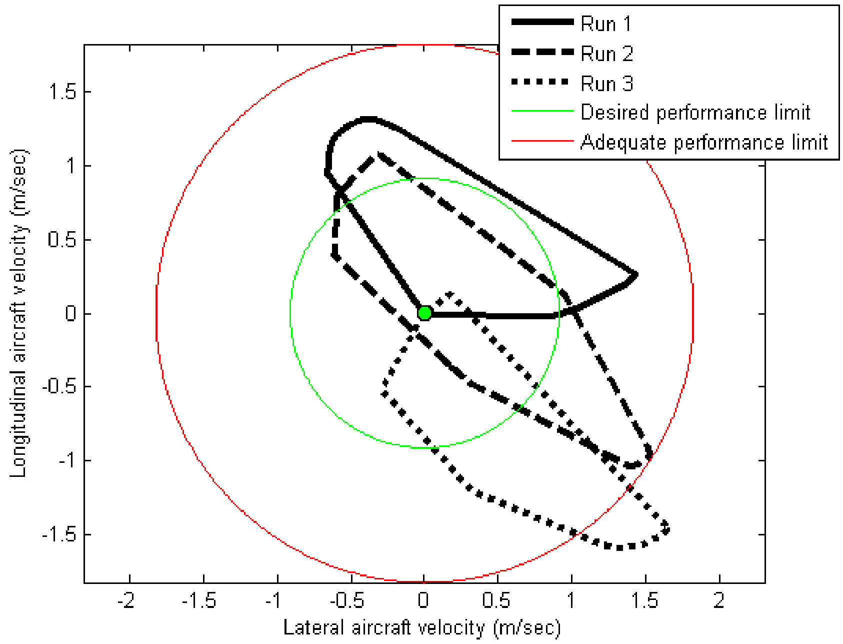


Figure 55 Maximum aircraft drift rate during MH1 using DVR strategy, Pilot 4

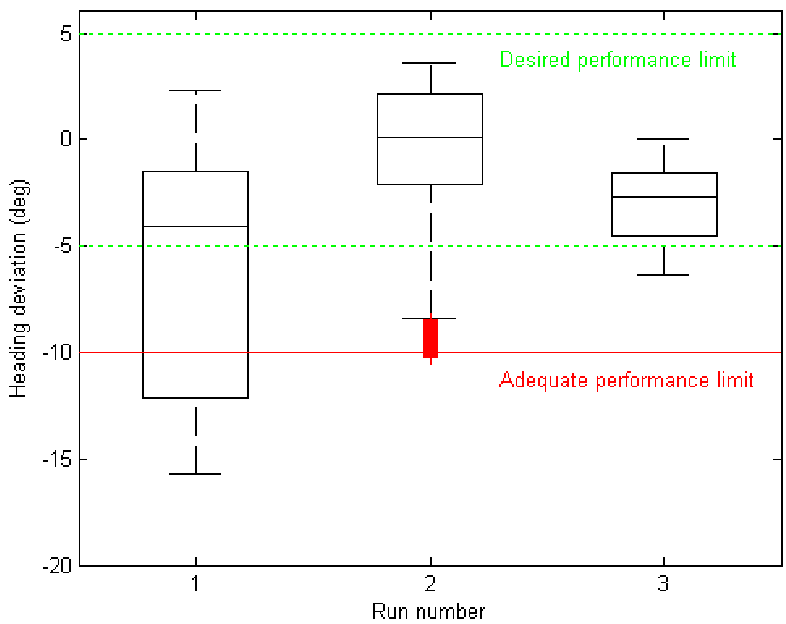


Figure 56 Maximum deviation of aircraft heading during MH1 using DVR strategy, Pilot 4

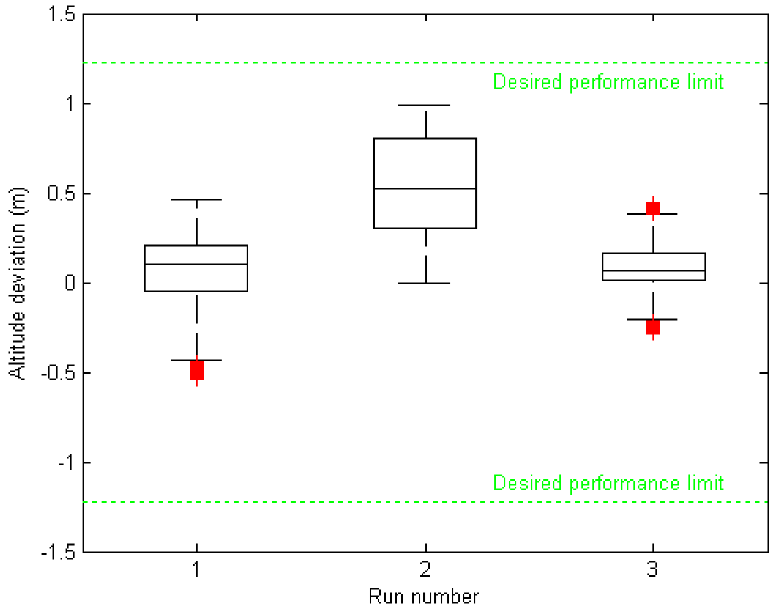


Figure 57 Maximum deviation of aircraft altitude during MH1 using DVR strategy, Pilot 3

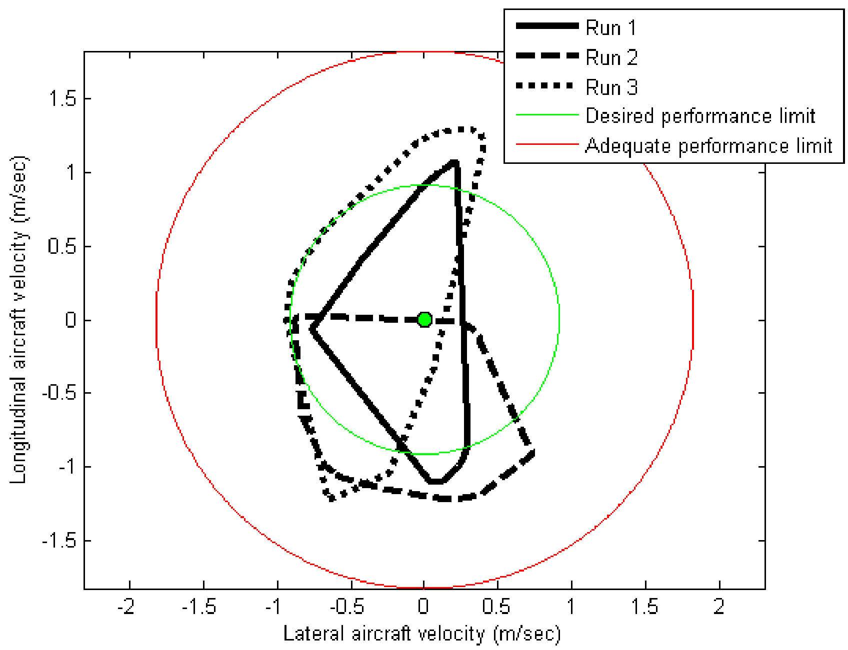


Figure 58 Maximum aircraft drift rate during MH1 using Boresighting reference strategy, Pilot 4

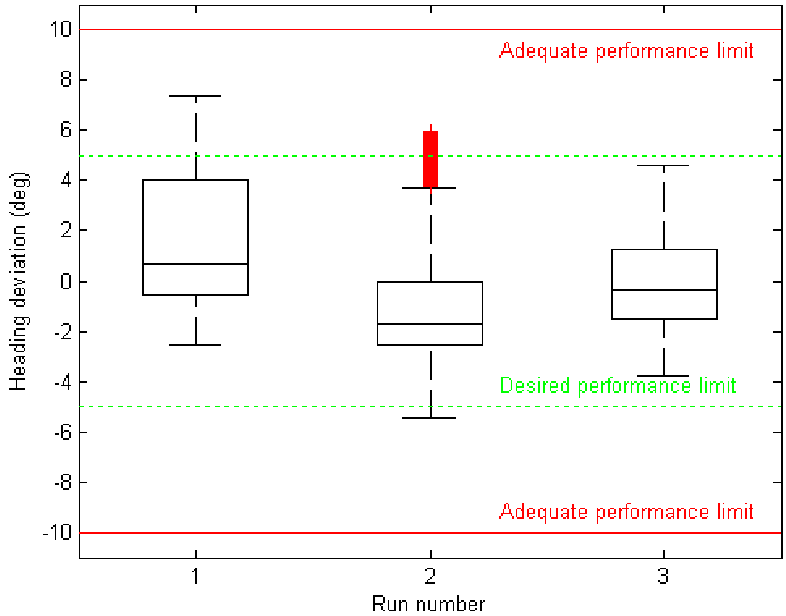


Figure 59 *Maximum deviation of aircraft heading during MH1 using Boresighting reference strategy, Pilot 4*

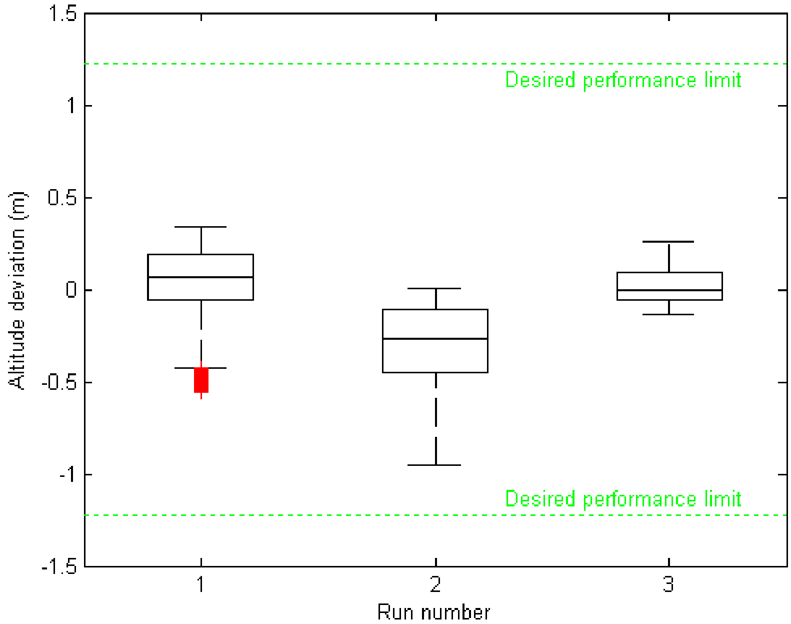


Figure 60 *Maximum deviation of aircraft altitude during MH1 using Boresighting reference strategy, Pilot 4*

E.4 Maritime Hover Manoeuvre, Moderate Seas (MH2)

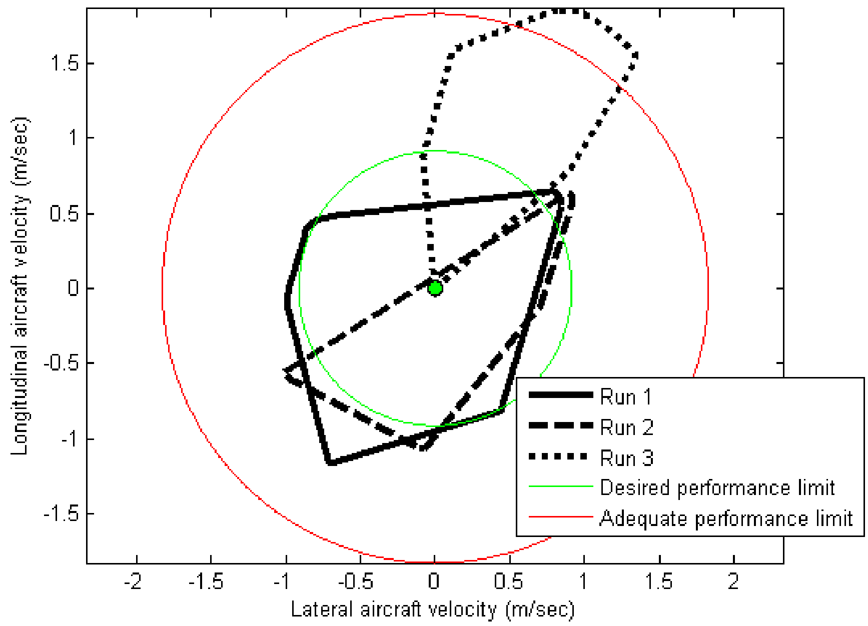


Figure 61 Maximum aircraft drift rate during MH2 using DVR strategy, Pilot 2

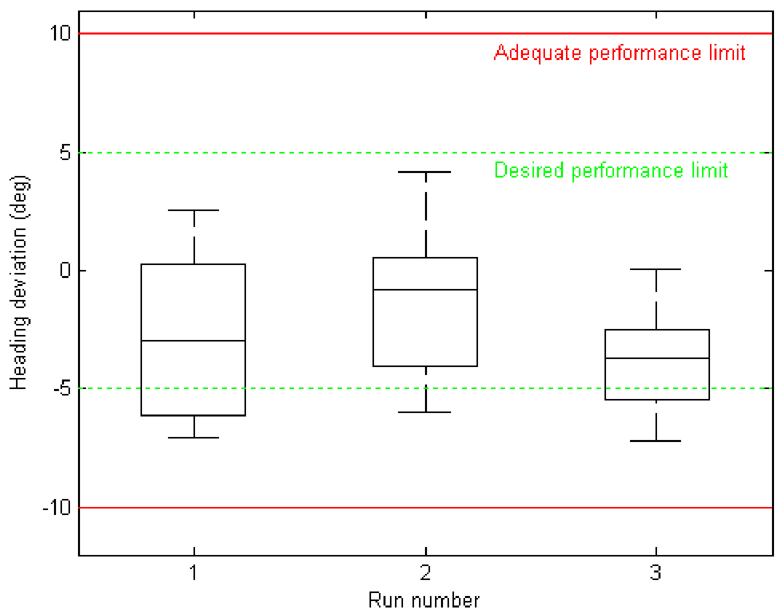


Figure 62 Maximum deviation of aircraft heading during MH2 using DVR strategy, Pilot 2

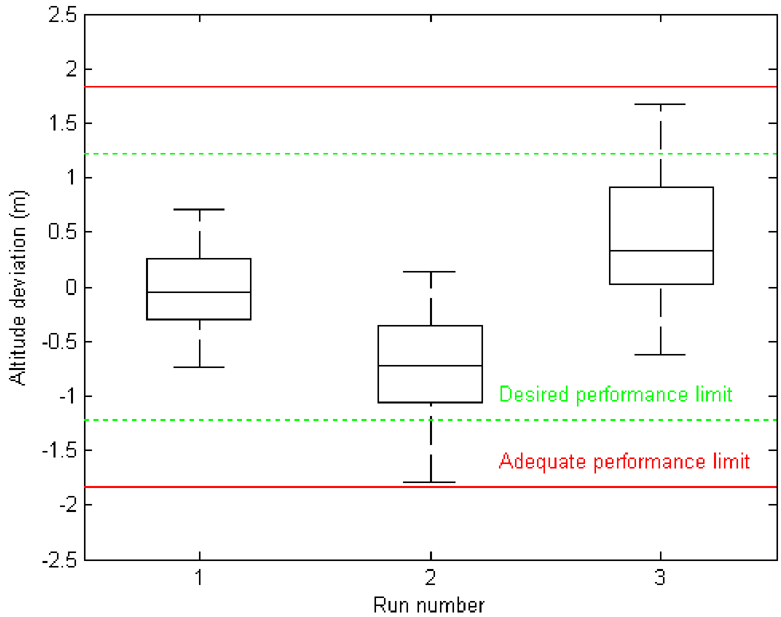


Figure 63 Maximum deviation of aircraft altitude during MH2 using DVR strategy, Pilot 2

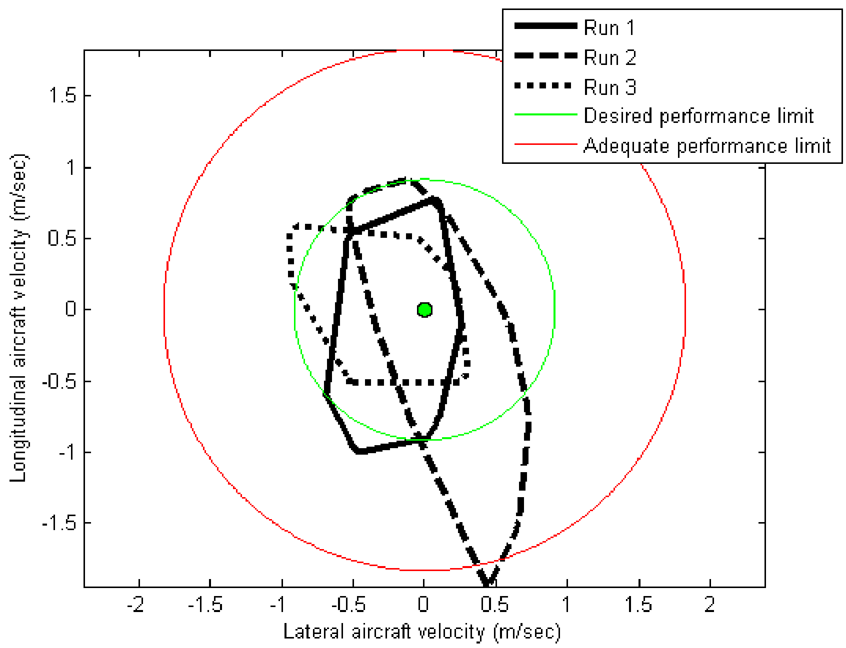


Figure 64 Maximum aircraft drift rate during MH2 using Boresighting reference strategy, Pilot 2

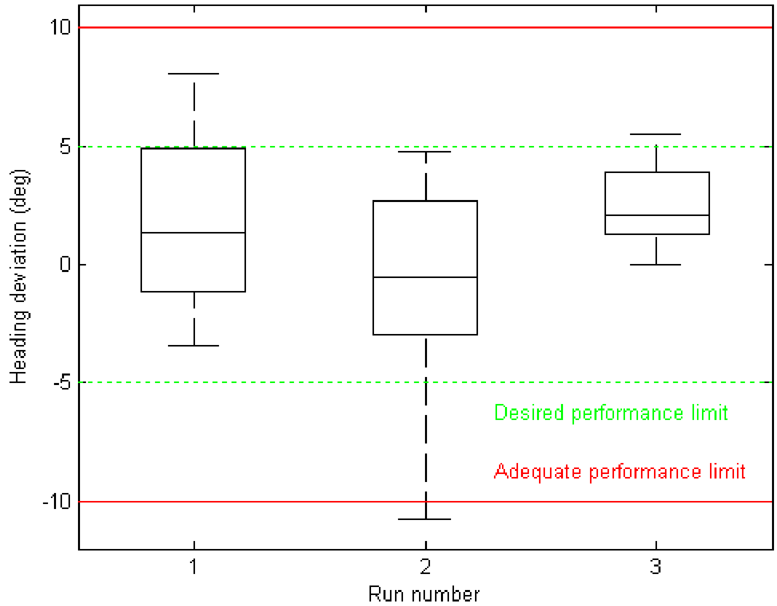


Figure 65 Maximum deviation of aircraft heading during MH2 using Boresighting reference strategy, Pilot 2

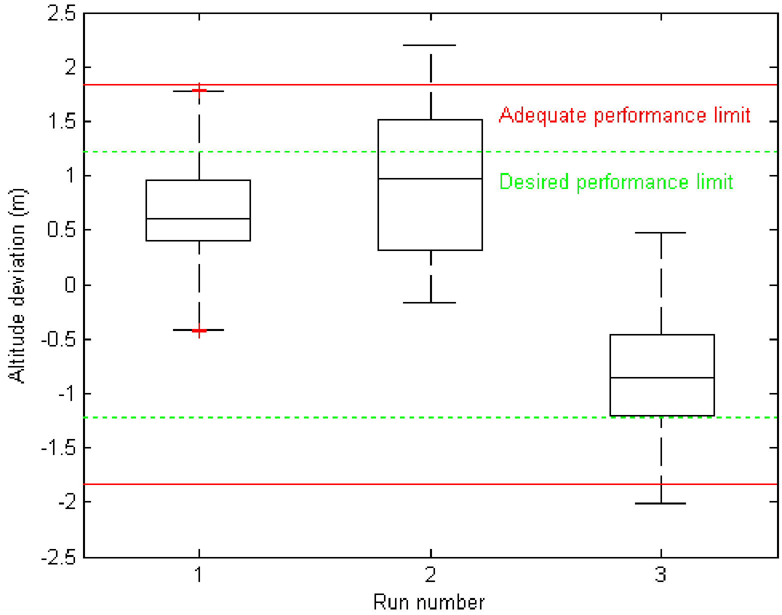


Figure 66 Maximum deviation of aircraft altitude during MH2 using Boresighting reference strategy, Pilot 2

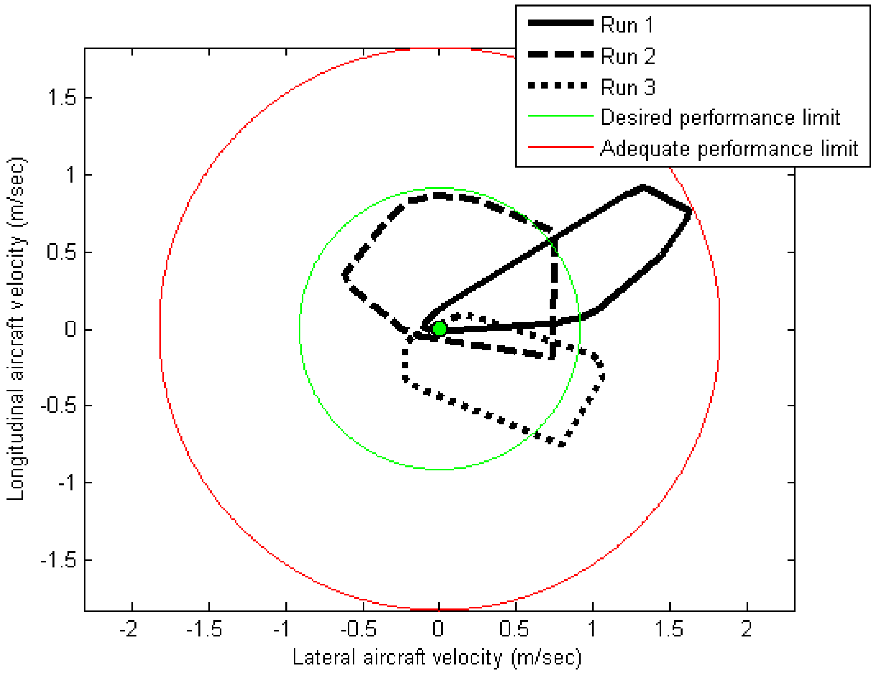


Figure 67 Maximum aircraft drift rate during MH2 using DVR strategy, Pilot 3

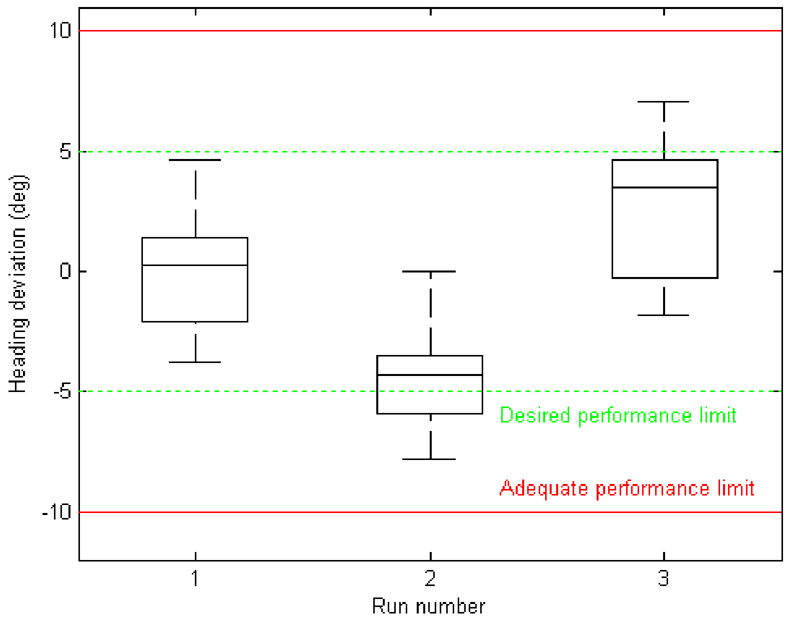


Figure 68 Maximum deviation of aircraft heading during MH2 using DVR strategy, Pilot 3

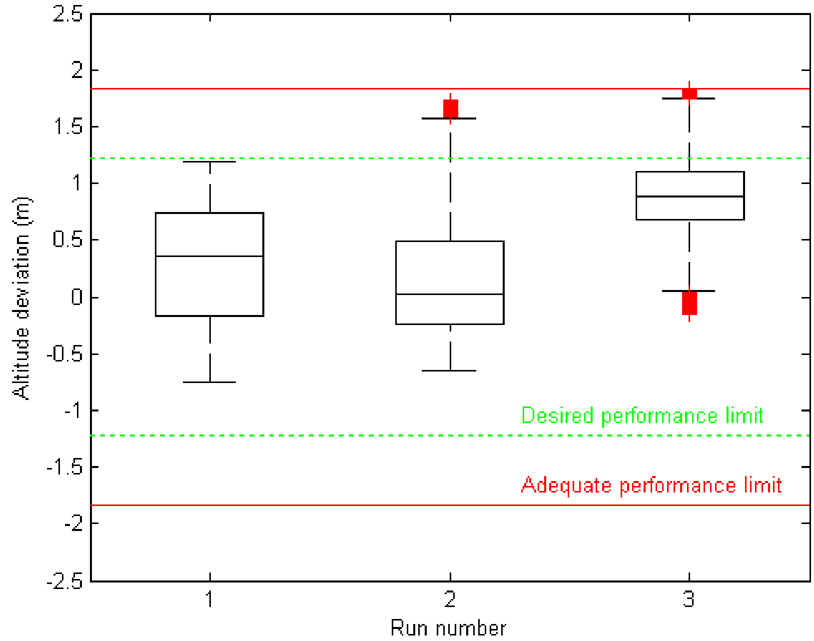


Figure 69 *Maximum deviation of aircraft altitude during MH2 using DVR strategy, Pilot 2*

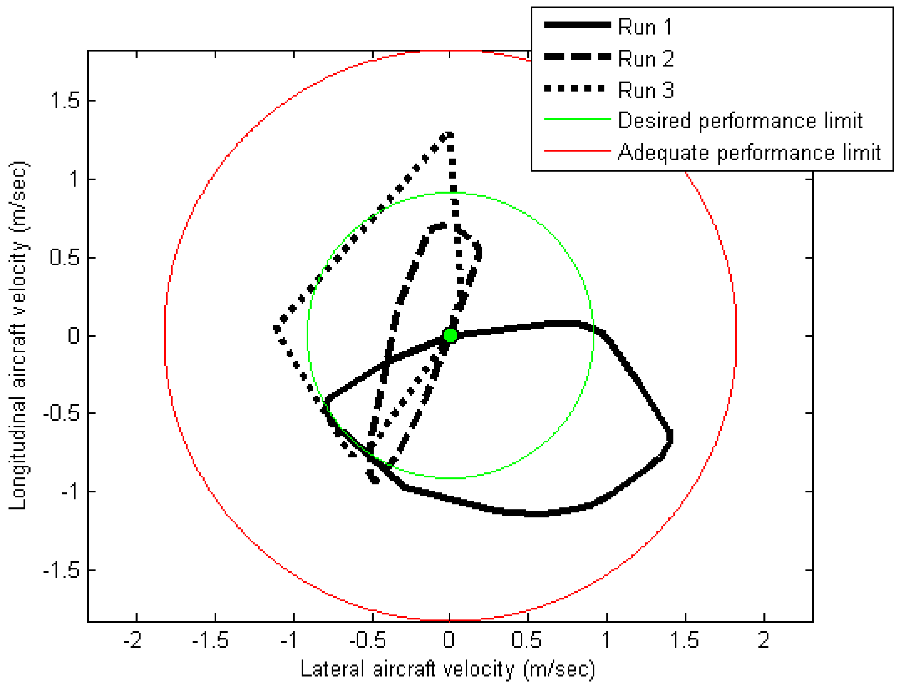


Figure 70 *Maximum aircraft drift rate during MH2 using Boresighting reference strategy, Pilot 3*

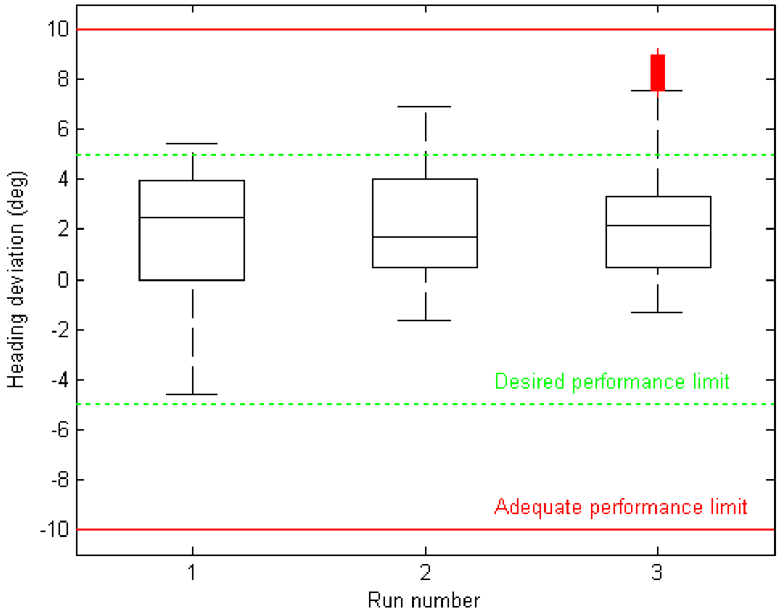


Figure 71 Maximum deviation of aircraft heading during MH2 using Boresighting reference strategy, Pilot 3

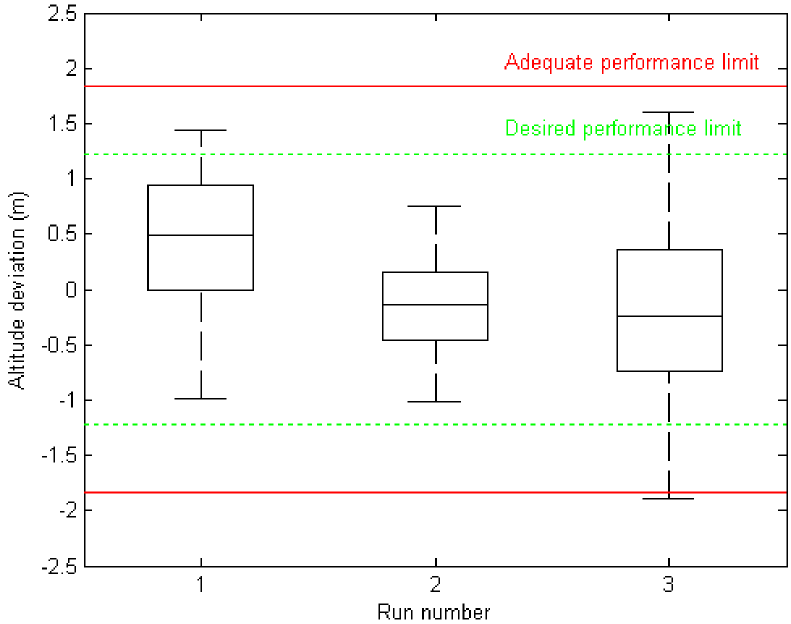


Figure 72 Maximum deviation of aircraft altitude during MH2 using Boresighting reference strategy, Pilot 3

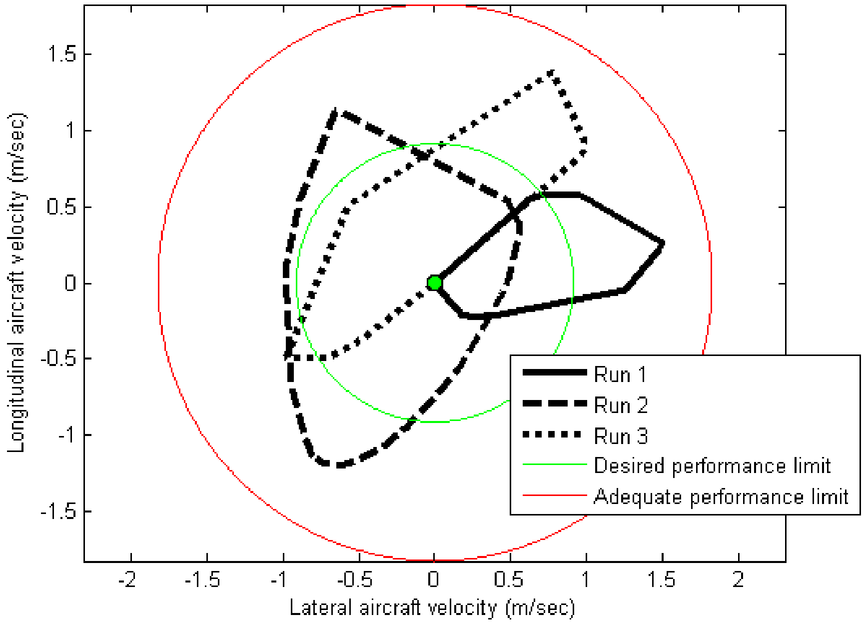


Figure 73 Maximum aircraft drift rate during MH2 using DVR strategy, Pilot 4

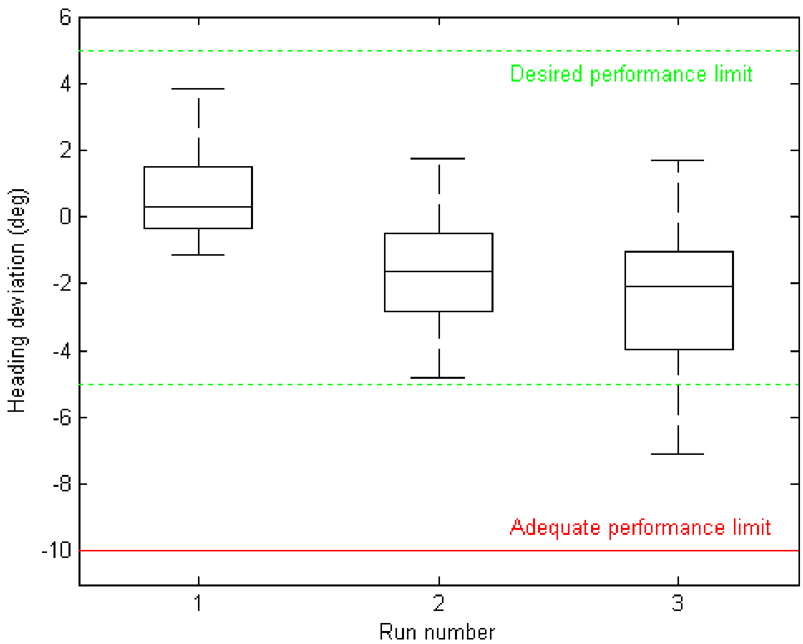


Figure 74 Maximum deviation of aircraft heading during MH2 using DVR strategy, Pilot 4

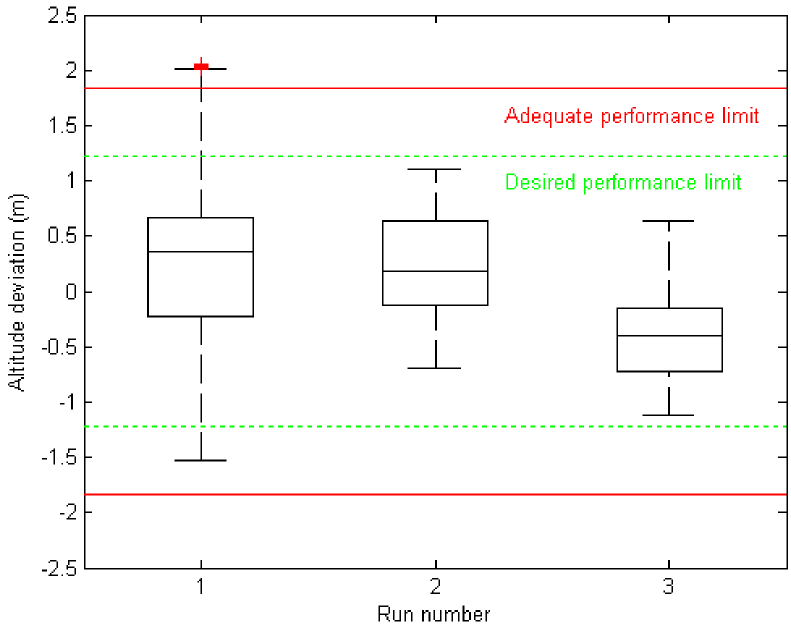


Figure 75 Maximum deviation of aircraft altitude during MH2 using DVR strategy, Pilot 4

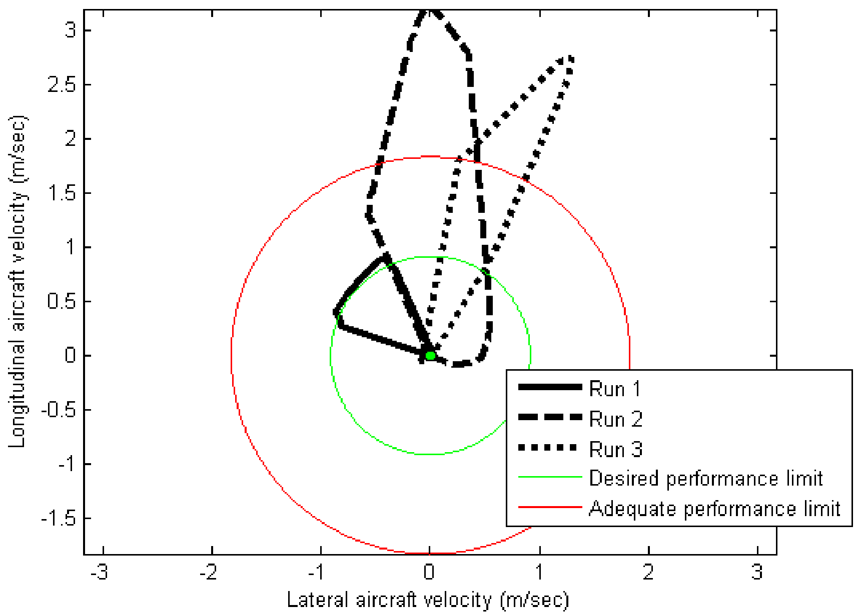


Figure 76 Maximum aircraft drift rate during MH2 using Boresighting reference strategy, Pilot 4

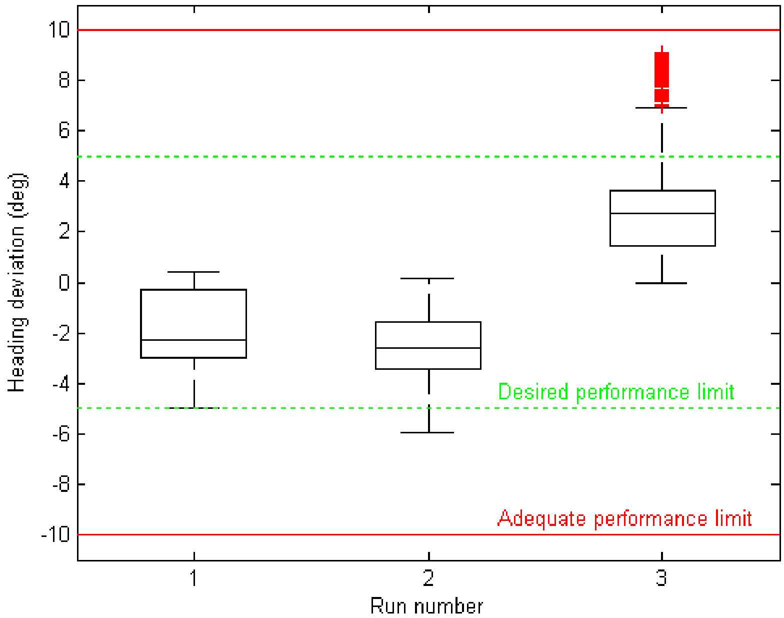


Figure 77 Maximum deviation of aircraft heading during MH2 using Boresighting reference strategy, Pilot 4

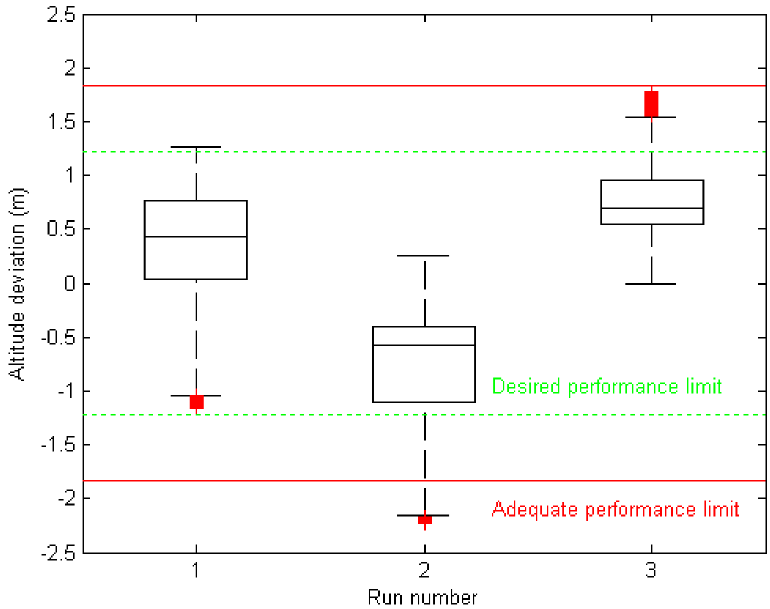


Figure 78 Maximum deviation of aircraft altitude during MH2 using Boresighting reference strategy, Pilot 4

E.5 Maritime Hover Manoeuvre, Rough Seas (MH3)

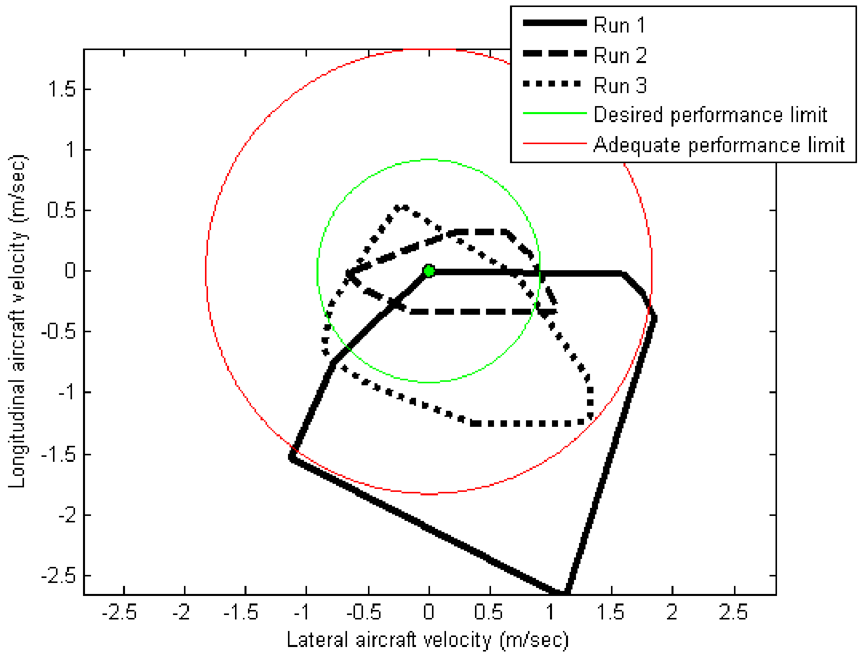


Figure 79 Maximum aircraft drift rate during MH3 using DVR strategy, Pilot 2

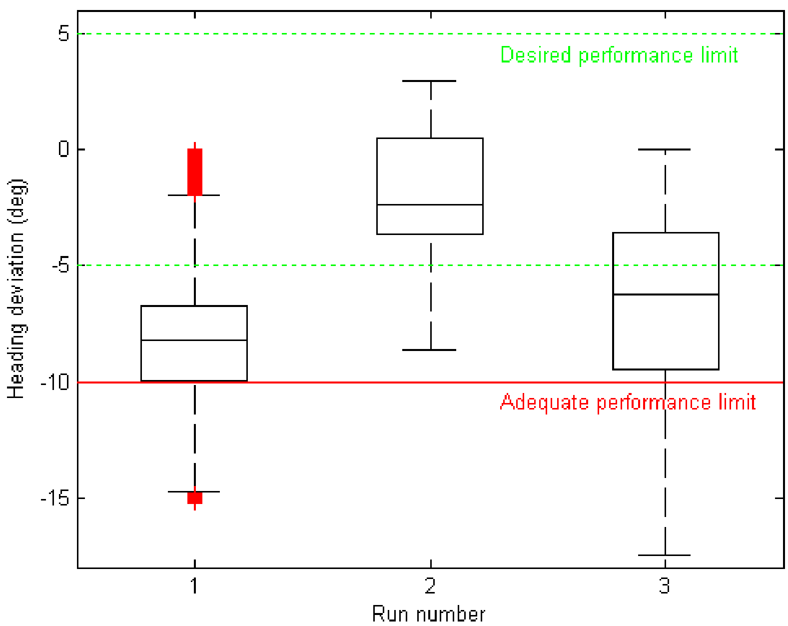


Figure 80 Maximum deviation of aircraft heading during MH3 using DVR strategy, Pilot 2

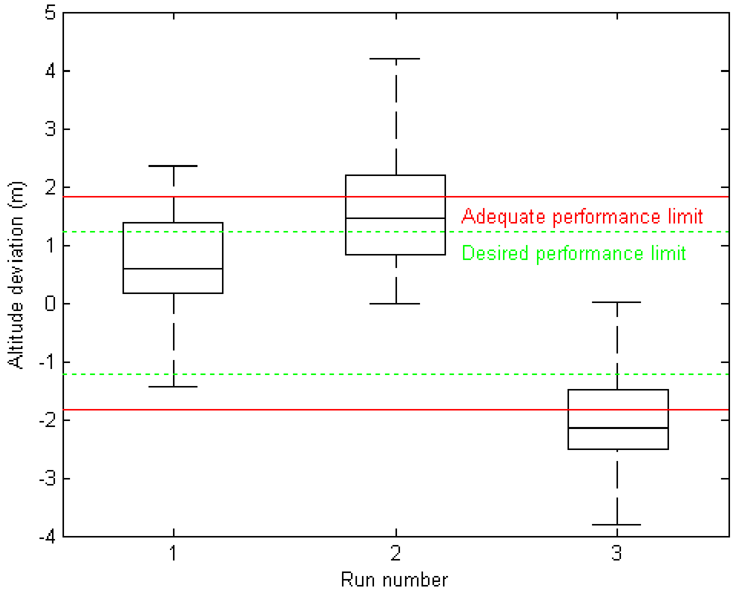


Figure 81 Maximum deviation of aircraft altitude during MH3 using DVR strategy, Pilot 2

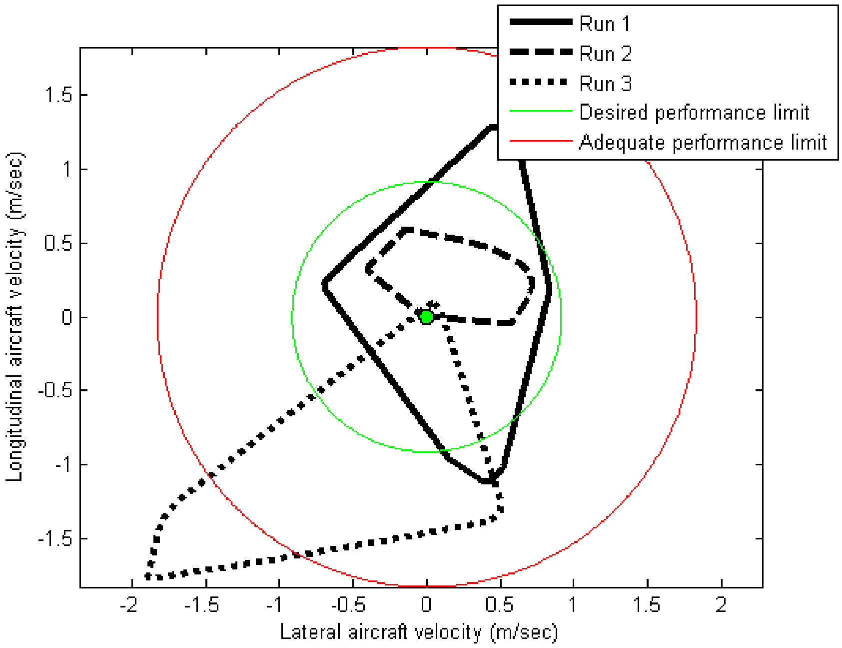


Figure 82 Maximum aircraft drift rate during MH3 using Boresighting reference strategy, Pilot 2

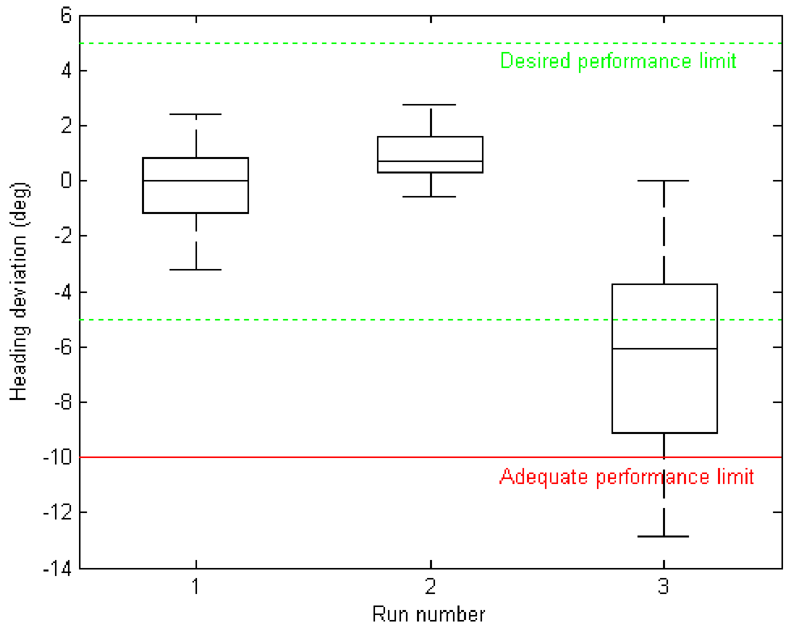


Figure 83 Maximum deviation of aircraft heading during MH3 using Boresighting reference strategy, Pilot 2

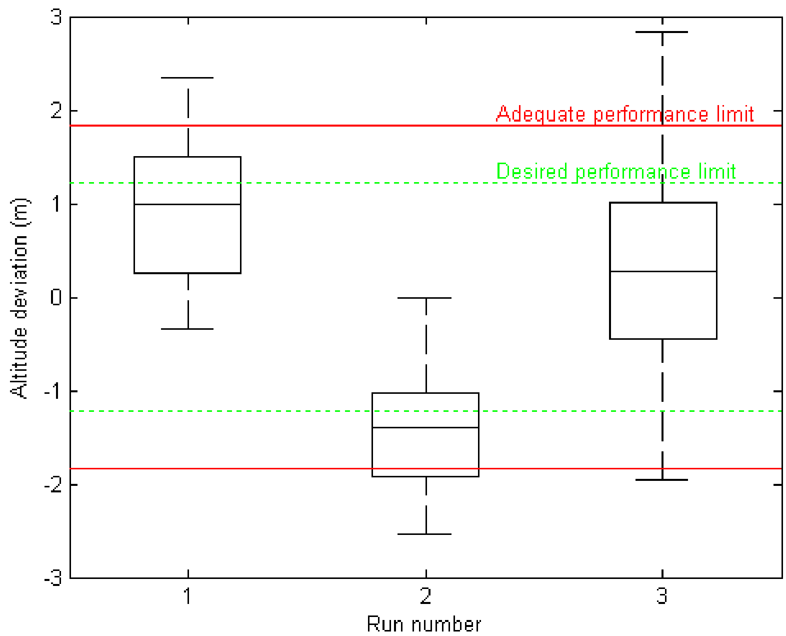


Figure 84 Maximum deviation of aircraft altitude during MH3 using Boresighting reference strategy, Pilot 2

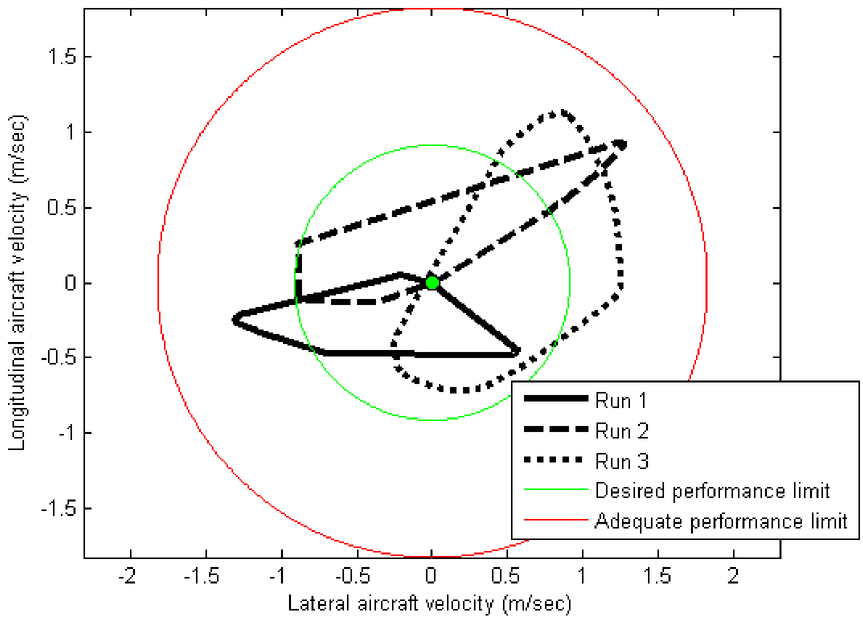


Figure 85 Maximum aircraft drift rate during MH3 using DVR strategy, Pilot 3

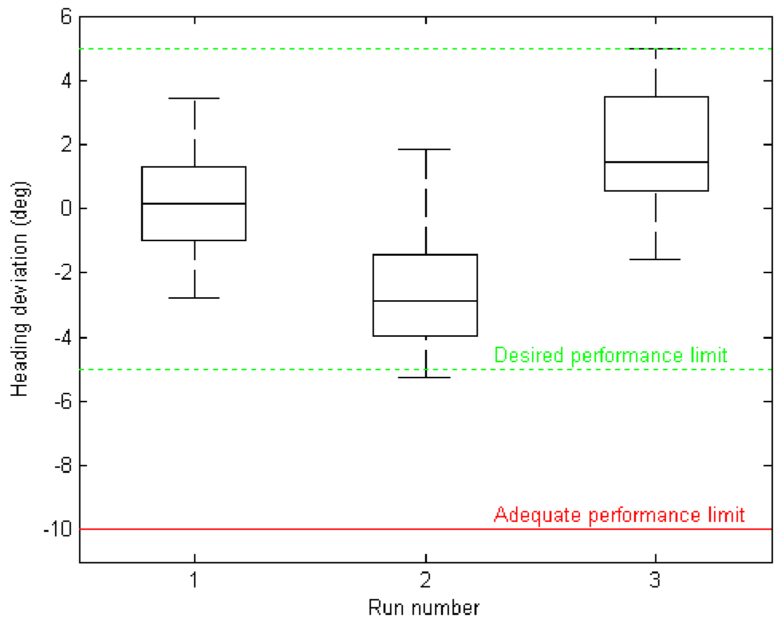


Figure 86 Maximum deviation of aircraft heading during MH3 using DVR strategy, Pilot 3

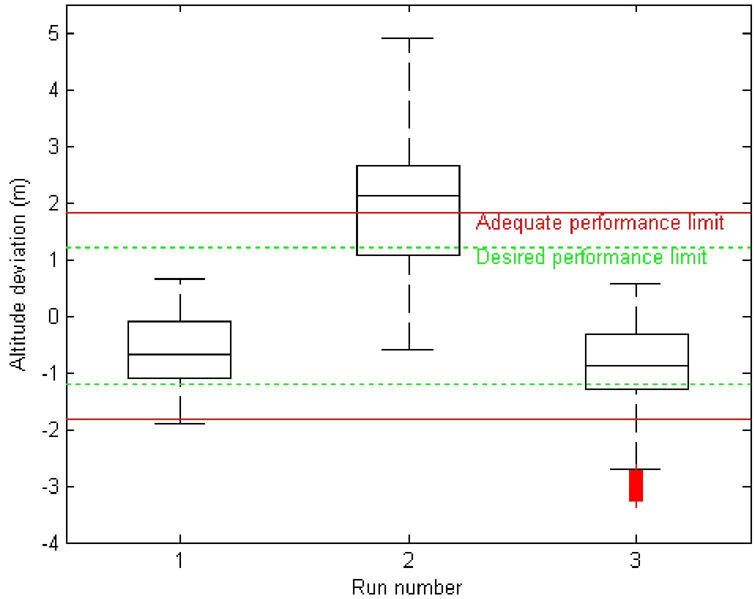


Figure 87 *Maximum deviation of aircraft altitude during MH3 using DVR strategy, Pilot 3*

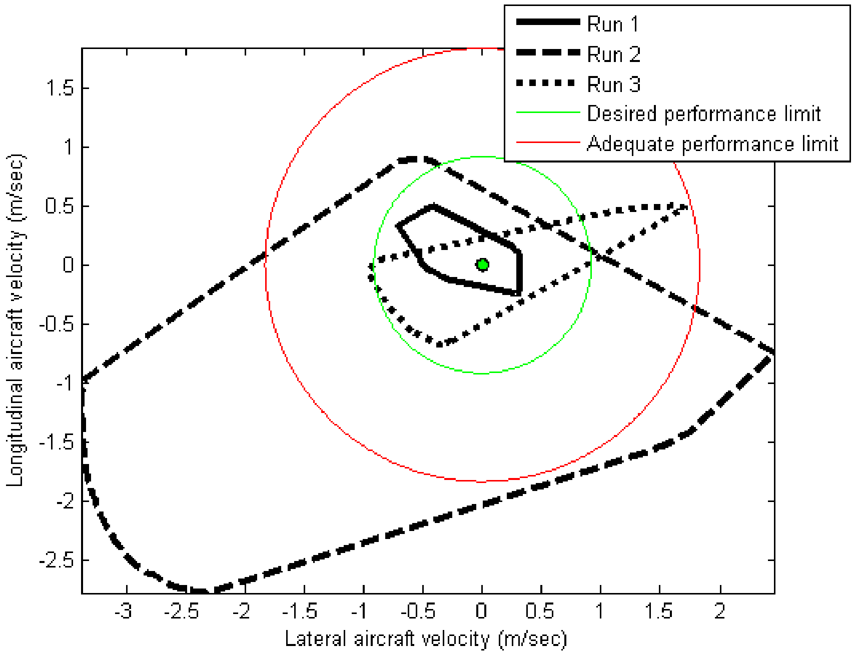


Figure 88 *Maximum aircraft drift rate during MH3 using Boresighting reference strategy, Pilot 3*

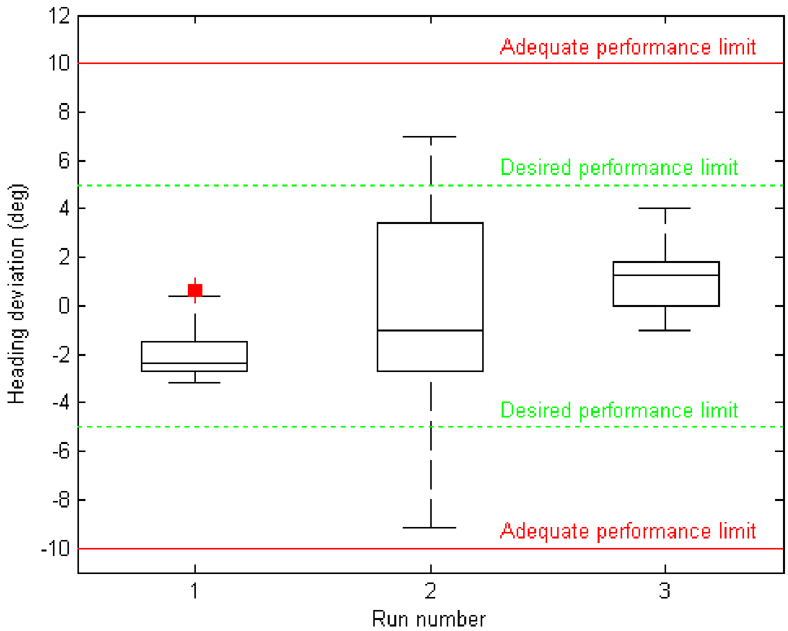


Figure 89   Maximum deviation of aircraft heading during MH3 using Boresighting reference strategy, Pilot 3

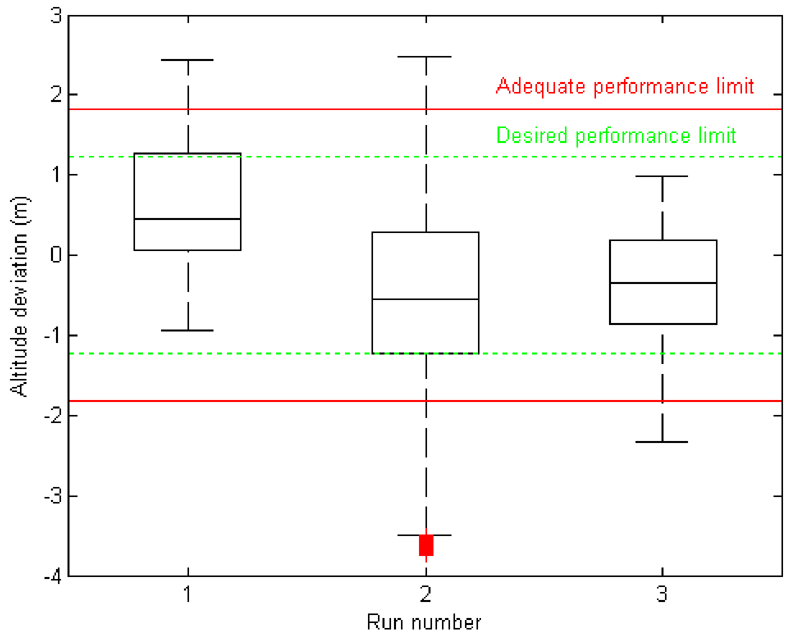


Figure 90   Maximum deviation of aircraft altitude during MH3 using Boresighting reference strategy, Pilot 3

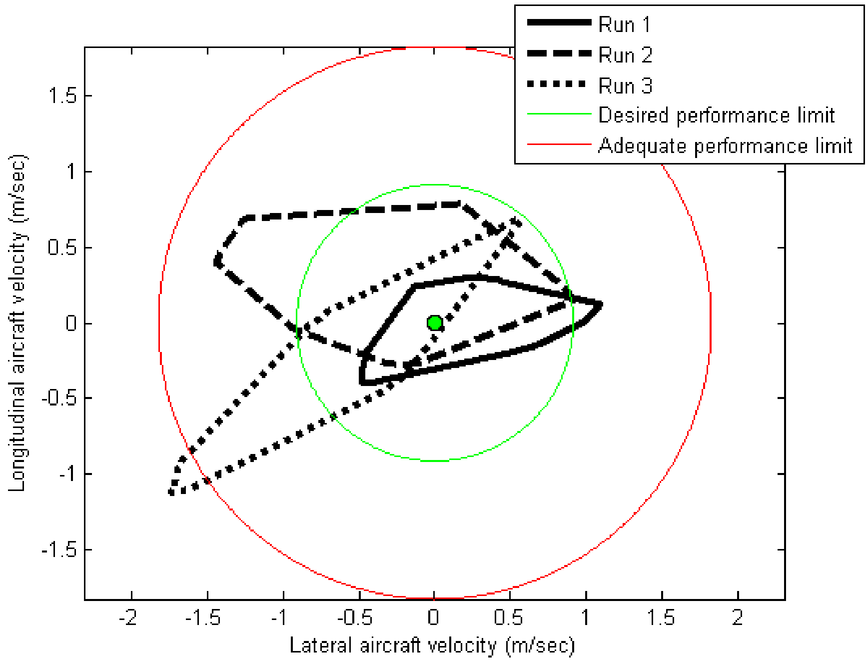


Figure 91 Maximum aircraft drift rate during MH3 using DVR strategy, Pilot 4

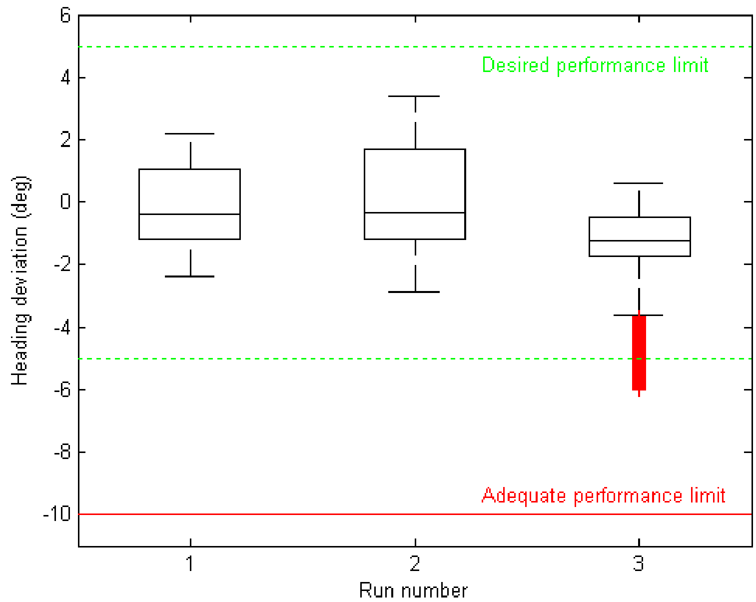


Figure 92 Maximum deviation of aircraft heading during MH3 using DVR strategy, Pilot 4

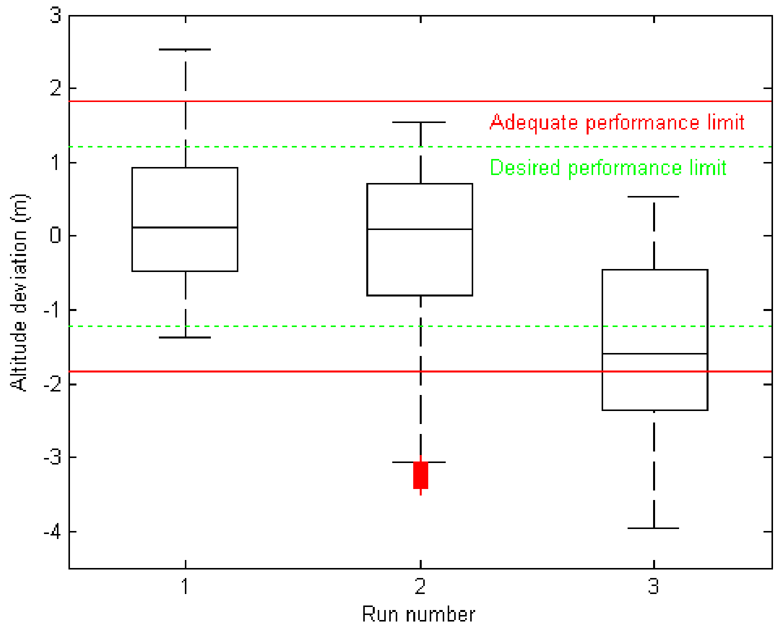


Figure 93 Maximum deviation of aircraft altitude during MH3 using DVR strategy, Pilot 4

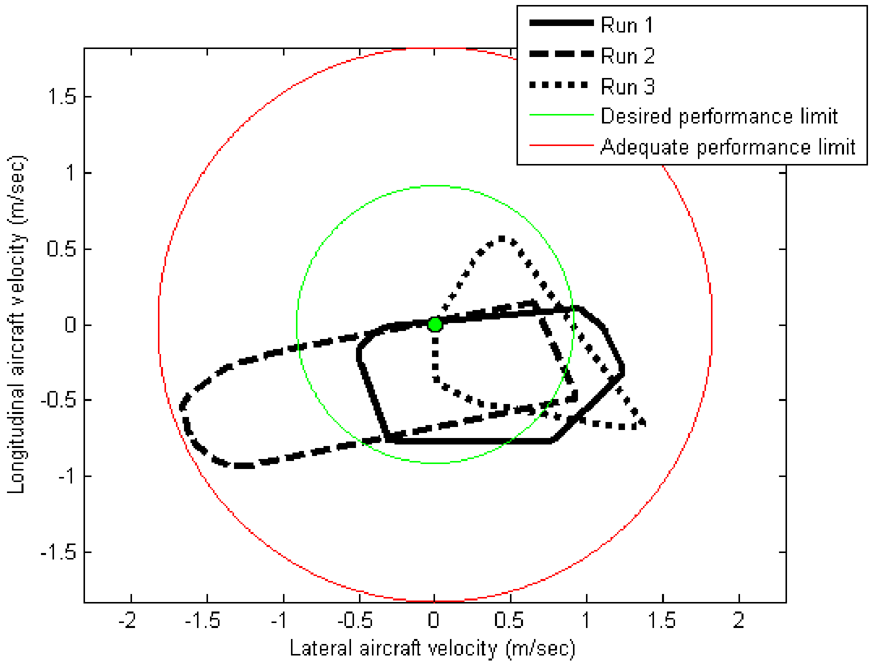


Figure 94 Maximum aircraft drift rate during MH3 using Boresighting reference strategy, Pilot 4

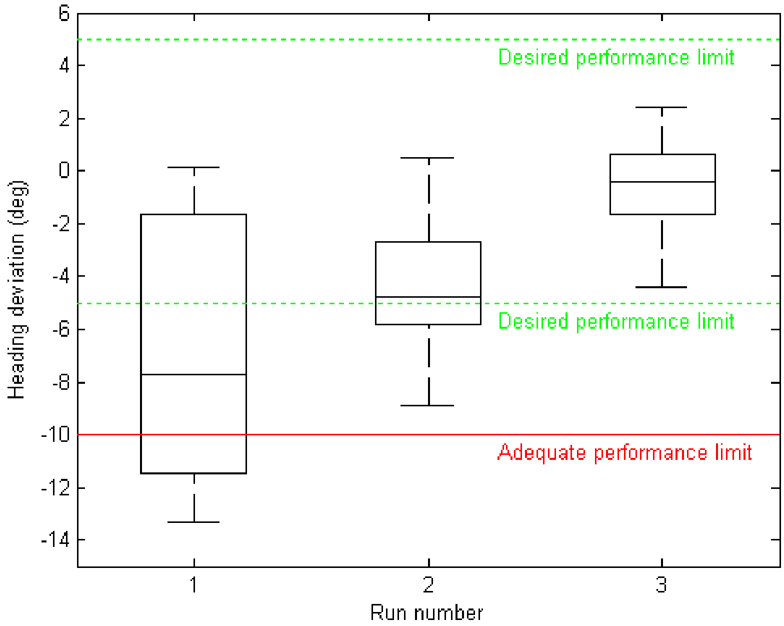


Figure 95 Maximum deviation of aircraft heading during MH3 using Boresighting reference strategy, Pilot 4

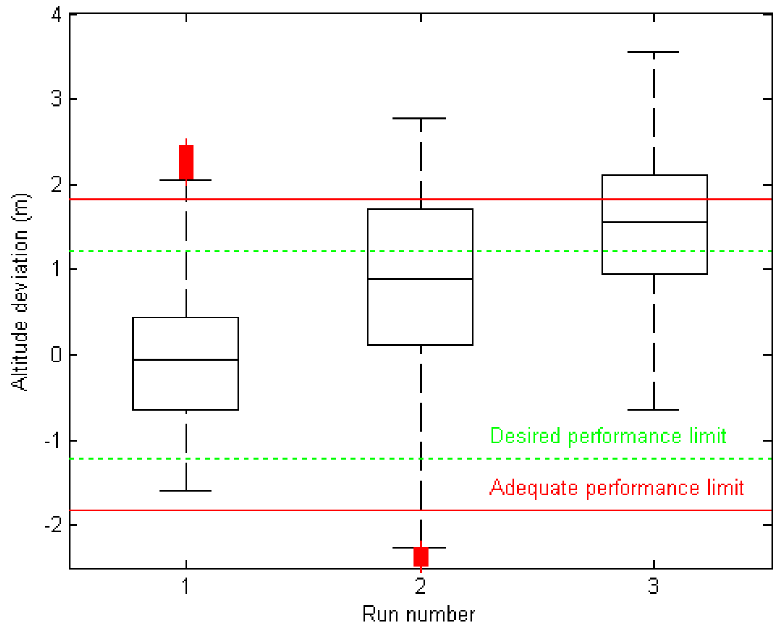


Figure 96 Maximum deviation of aircraft altitude during MH3 using Boresighting reference strategy, Pilot 4

Appendix F: Maximum Deviation during Manoeuvre, S-70B Seahawk Flight Model

F.1 ADS-33 Ground Hover

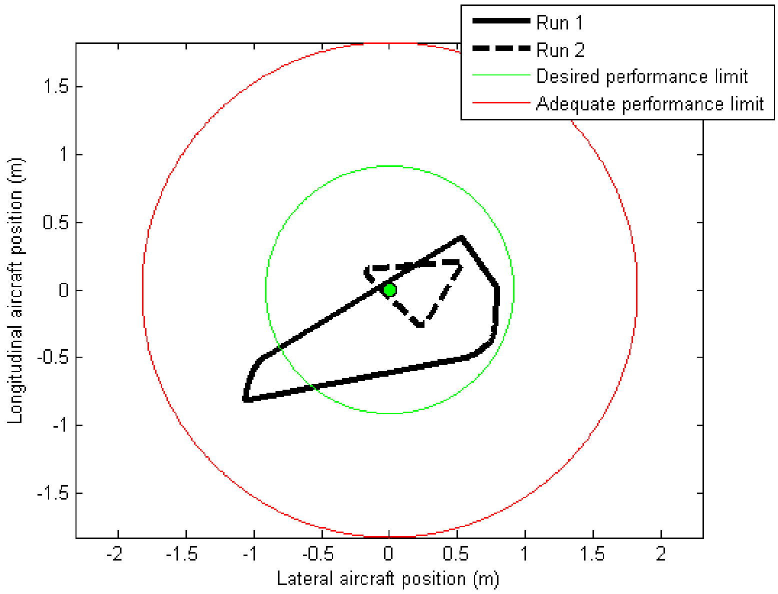


Figure 97 Maximum deviation of aircraft plan position during ADS-33 Ground Hover Manoeuvre, Pilot 2

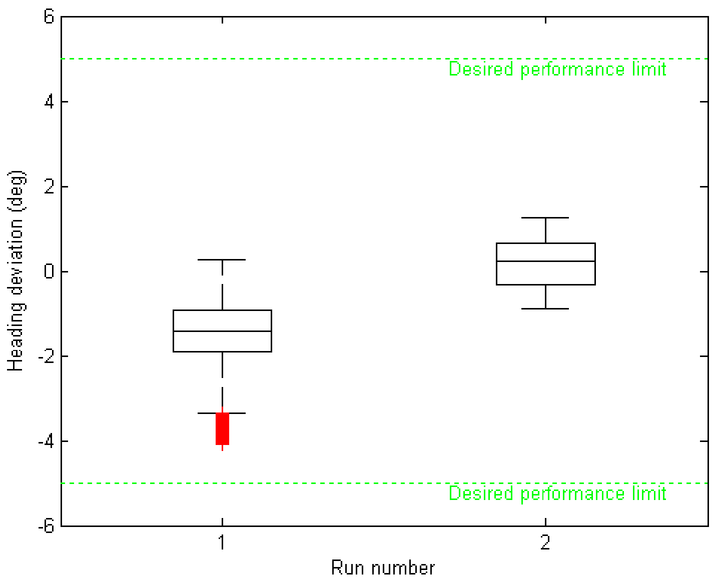


Figure 98 Maximum deviation of aircraft heading during ADS-33 Ground Hover Manoeuvre, Pilot 2

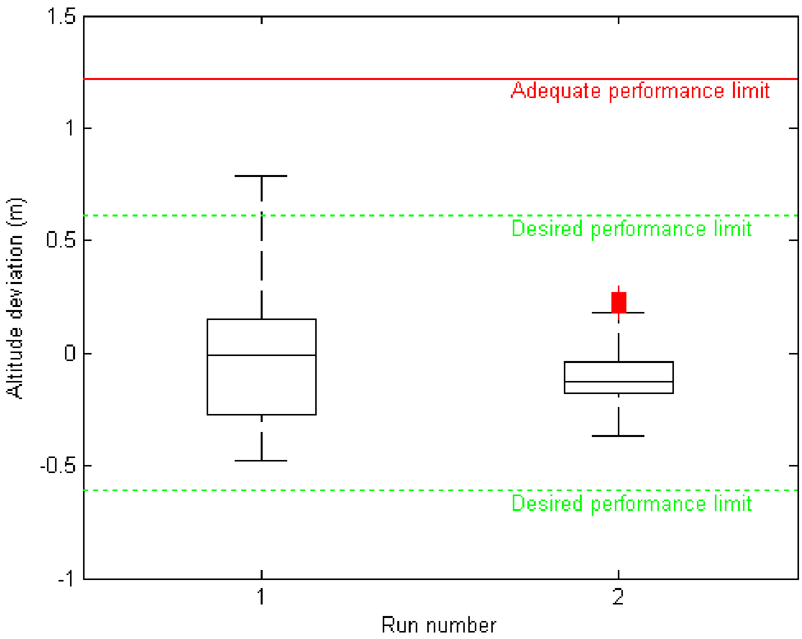


Figure 99 Maximum deviation of aircraft altitude during ADS-33 Ground Hover Manoeuvre, Pilot 2

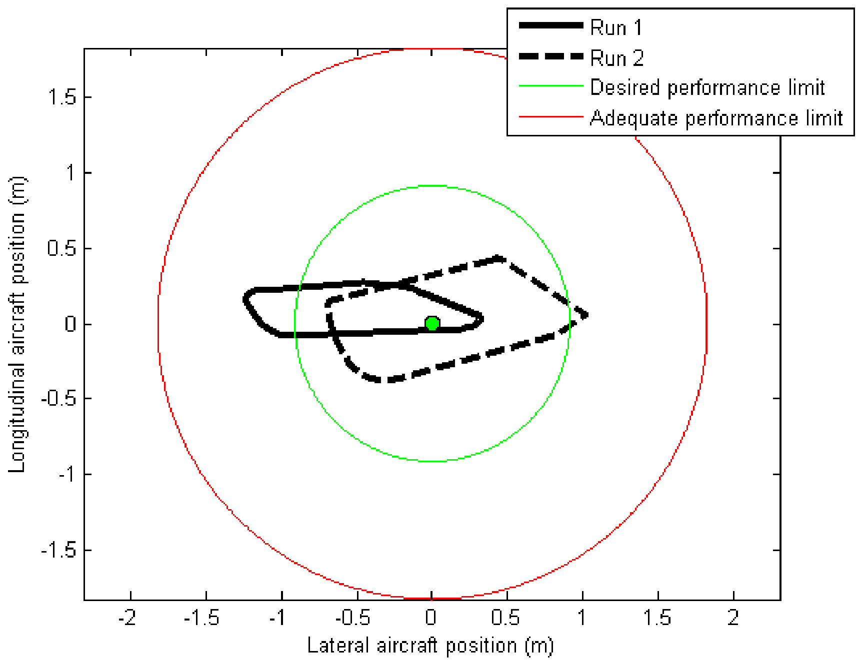


Figure 100 Maximum deviation of aircraft plan position during ADS-33 Ground Hover Manoeuvre, Pilot 3

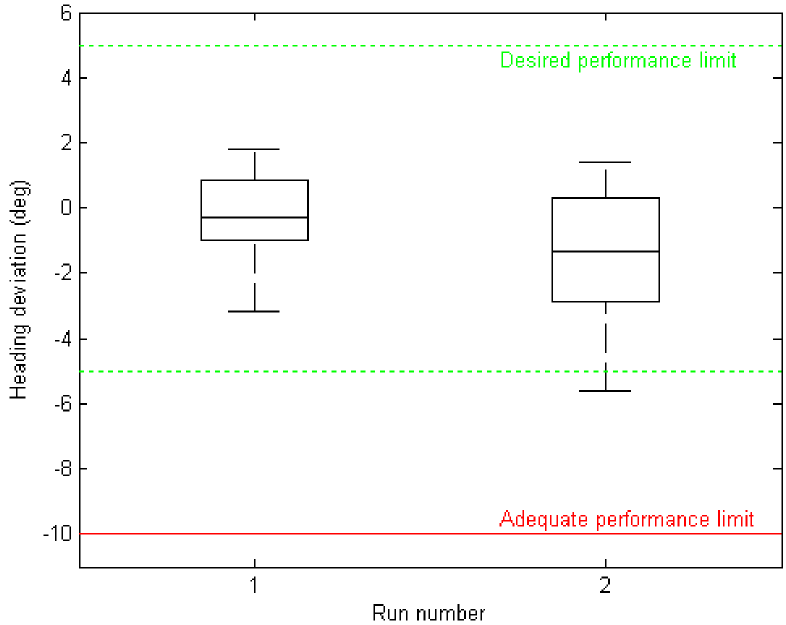


Figure 101 Maximum deviation of aircraft heading during ADS-33 Ground Hover Manoeuvre, Pilot 3

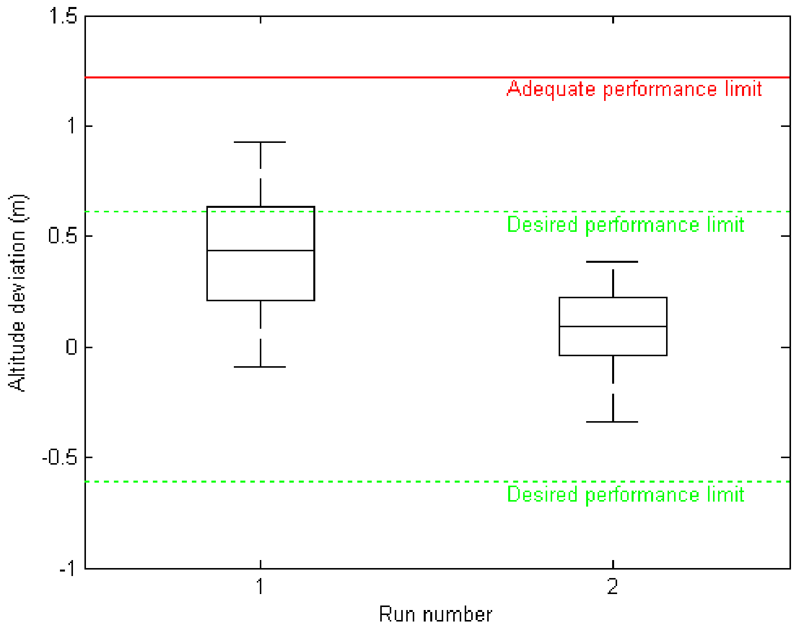


Figure 102 Maximum deviation of aircraft altitude during ADS-33 Ground Hover Manoeuvre, Pilot 3

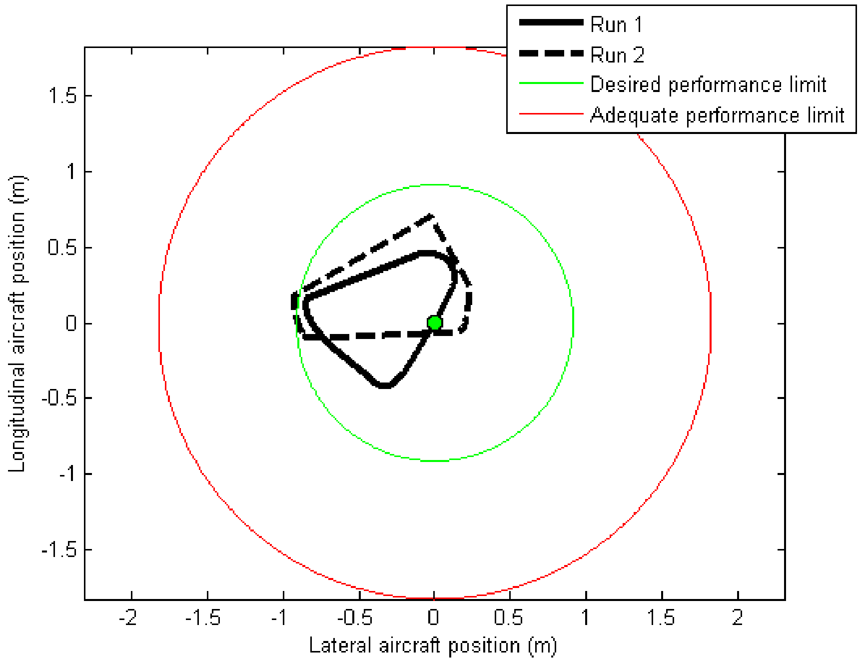


Figure 103 Maximum deviation of aircraft plan position during ADS-33 Ground Hover Manoeuvre, Pilot 4

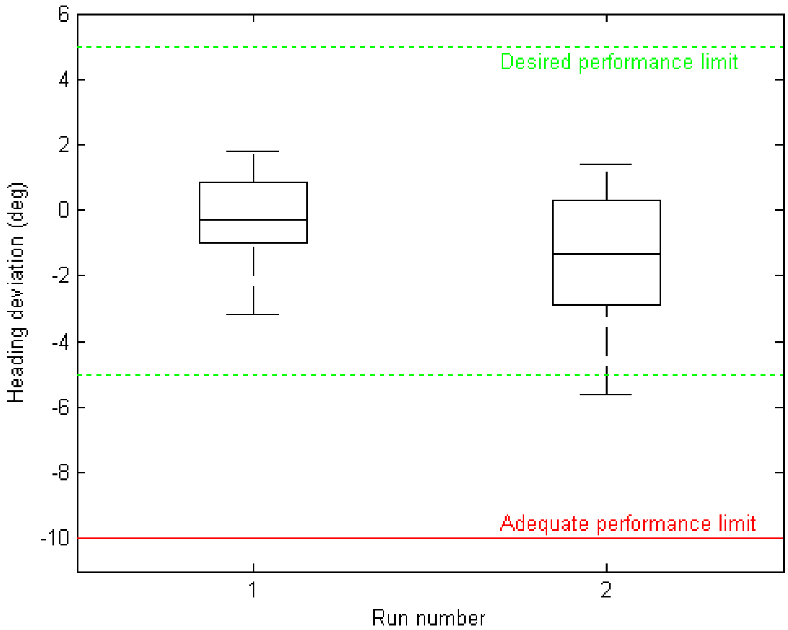


Figure 104 Maximum deviation of aircraft heading during ADS-33 Ground Hover Manoeuvre, Pilot 4

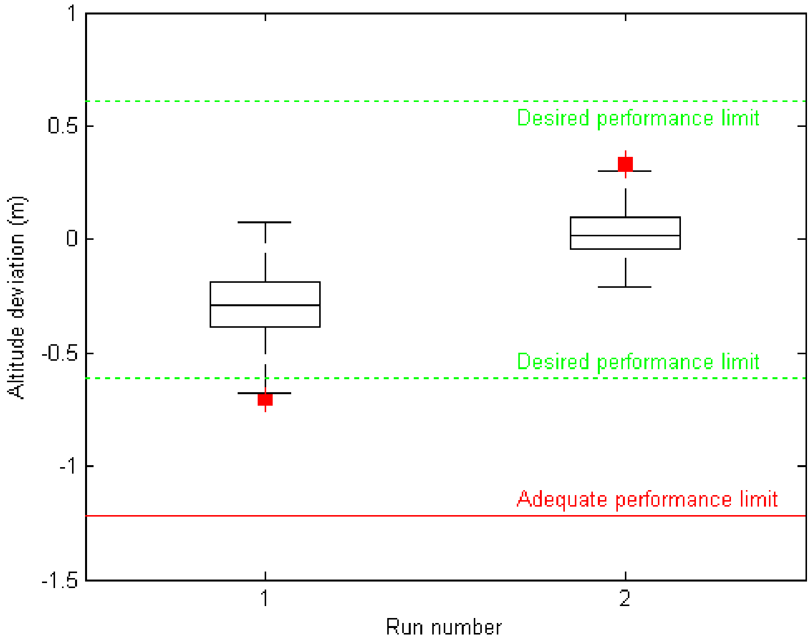


Figure 105 Maximum deviation of aircraft altitude during ADS-33 Ground Hover Manoeuvre, Pilot 4

F.2 ADS-33 Pirouette

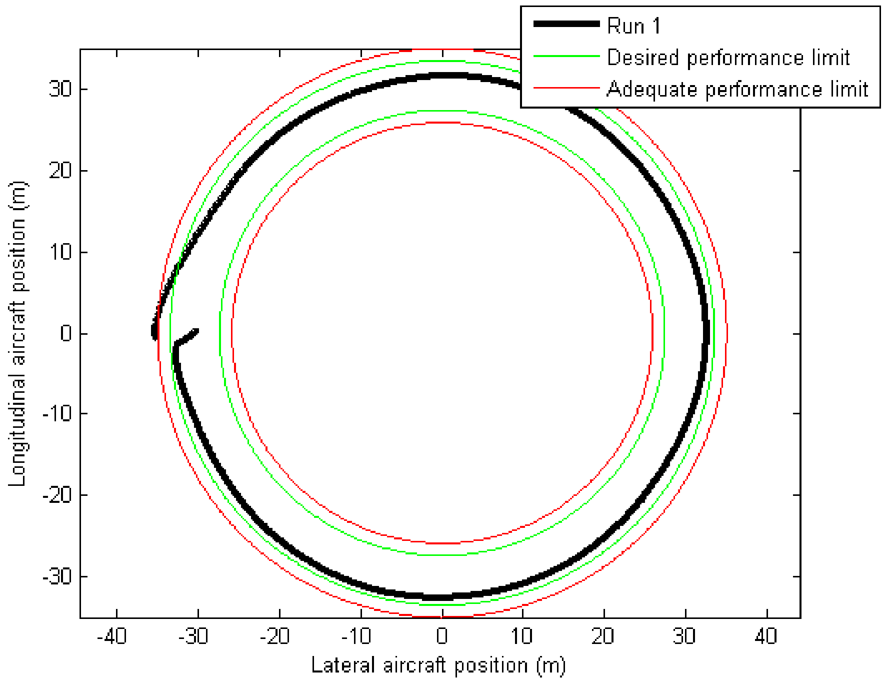


Figure 106 Maximum deviation of aircraft plan position during ADS-33 Pirouette Manoeuvre, Pilot 2, Run 1

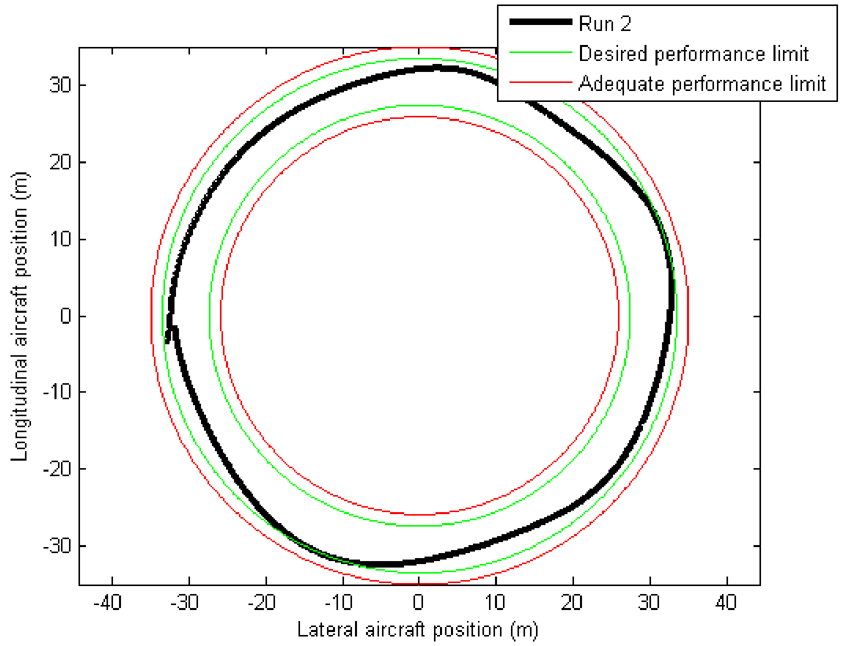


Figure 107 Maximum deviation of aircraft plan position during ADS-33 Pirouette Manoeuvre, Pilot 2, Run 2

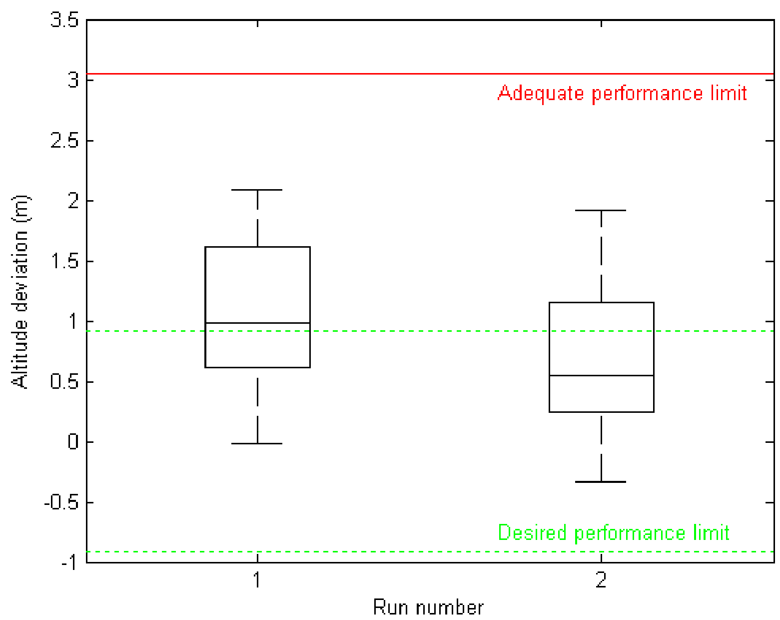


Figure 108 Maximum deviation of aircraft altitude during ADS-33 Pirouette Manoeuvre, Pilot 2

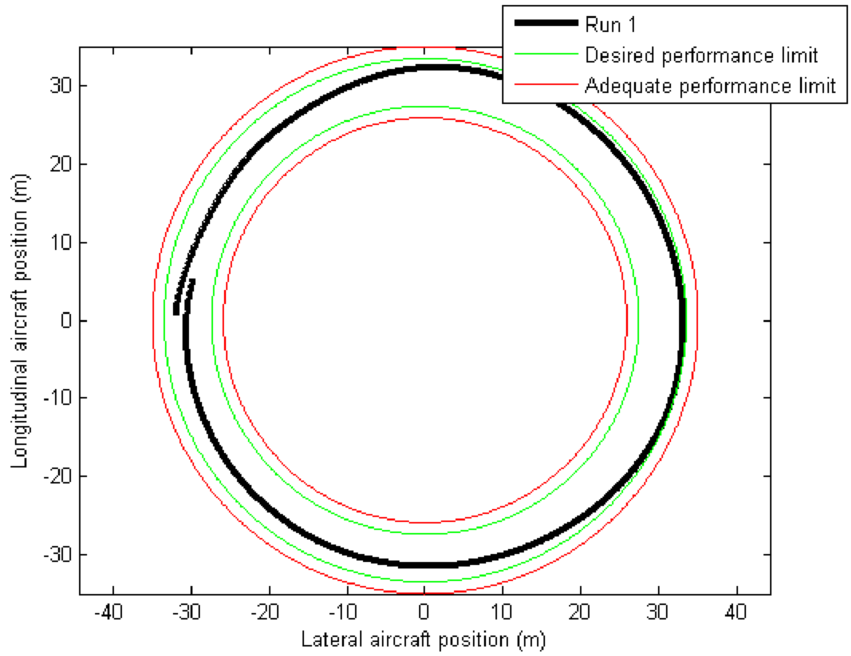


Figure 109 Maximum deviation of aircraft plan position during ADS-33 Pirouette Manoeuvre, Pilot 3, Run 1

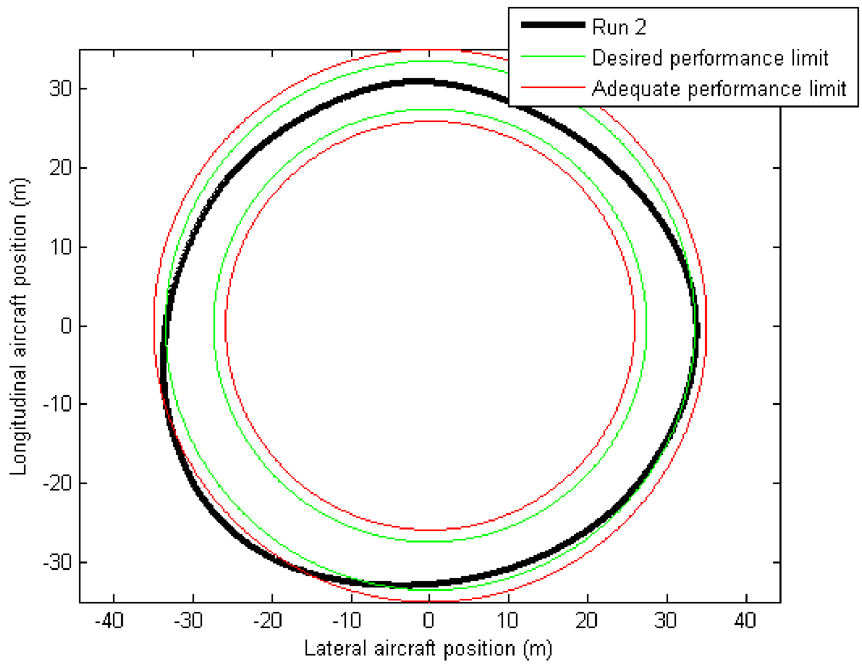


Figure 110 Maximum deviation of aircraft plan position during ADS-33 Pirouette Manoeuvre, Pilot 3, Run 2

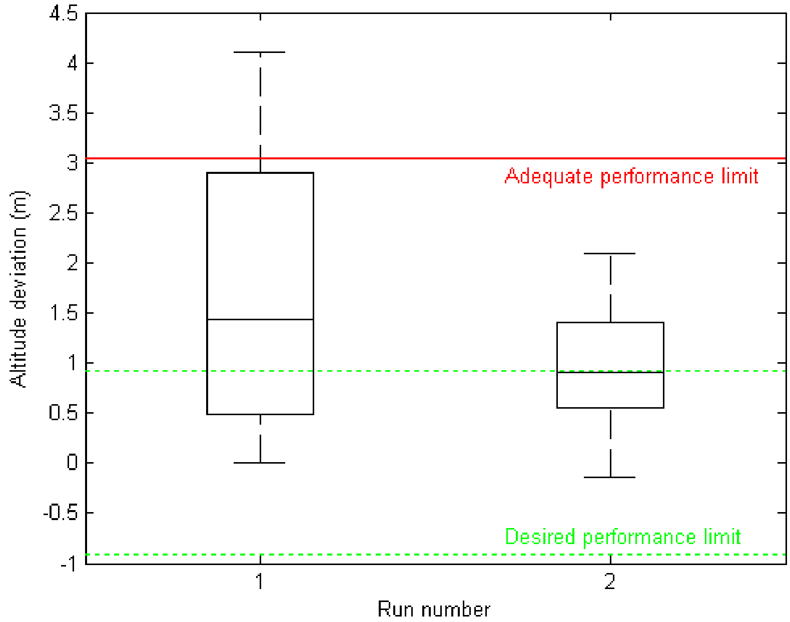


Figure 111 Maximum deviation of aircraft altitude during ADS-33 Pirouette Manoeuvre, Pilot 3

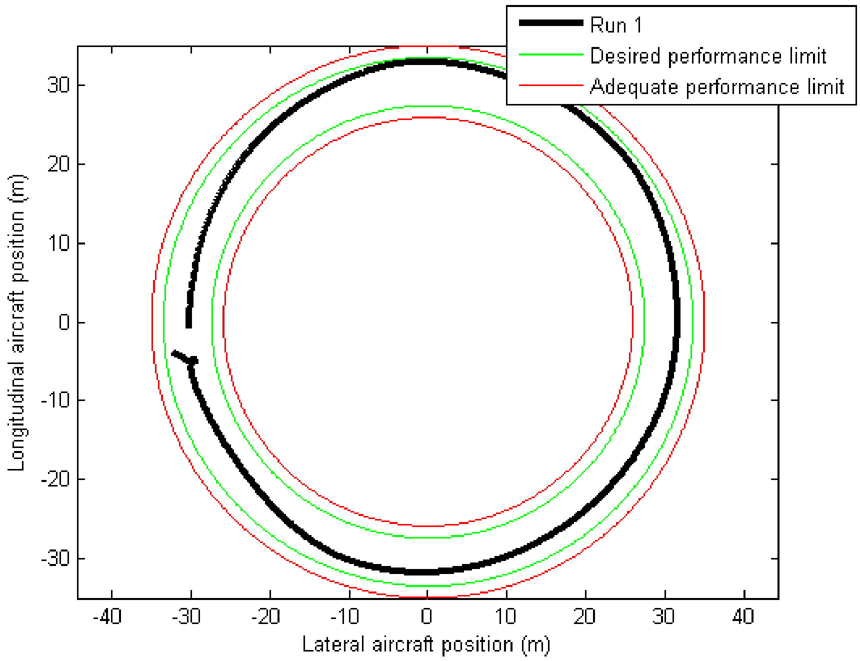


Figure 112 Maximum deviation of aircraft plan position during ADS-33 Pirouette Manoeuvre, Pilot 4, Run 1

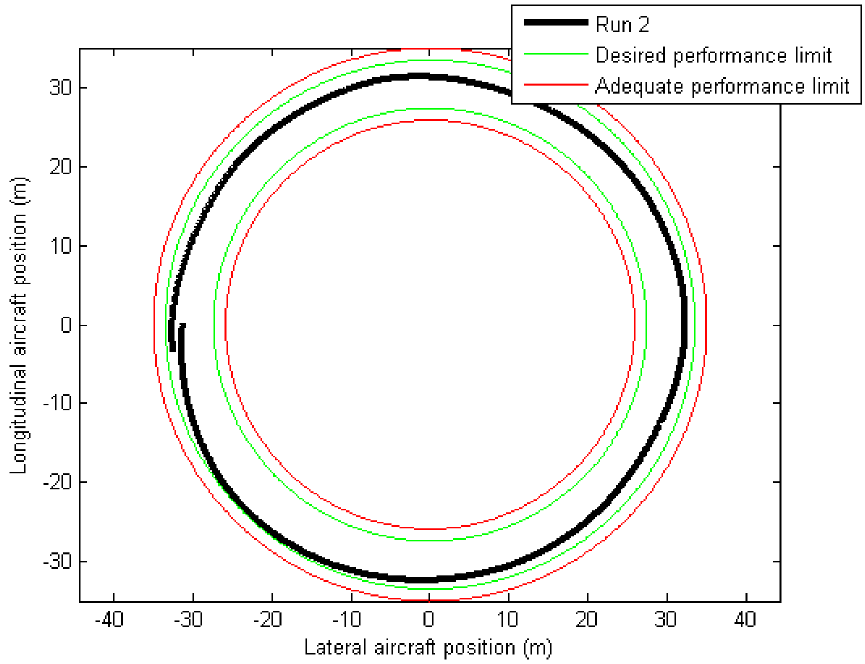


Figure 113 Maximum deviation of aircraft plan position during ADS-33 Pirouette Manoeuvre, Pilot 4, Run 2

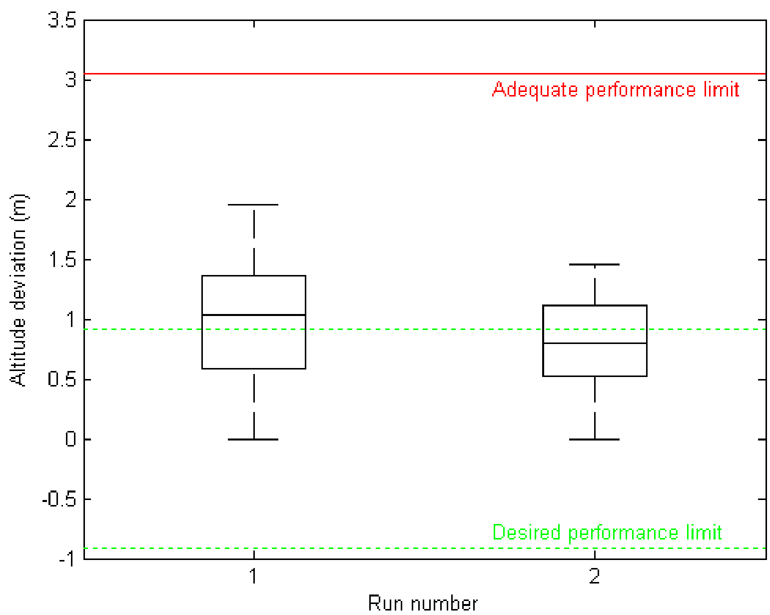


Figure 114 Maximum deviation of aircraft altitude during ADS-33 Pirouette Manoeuvre, Pilot 4

F.3 Maritime Hover Manoeuvre, Calm Seas (MH1)

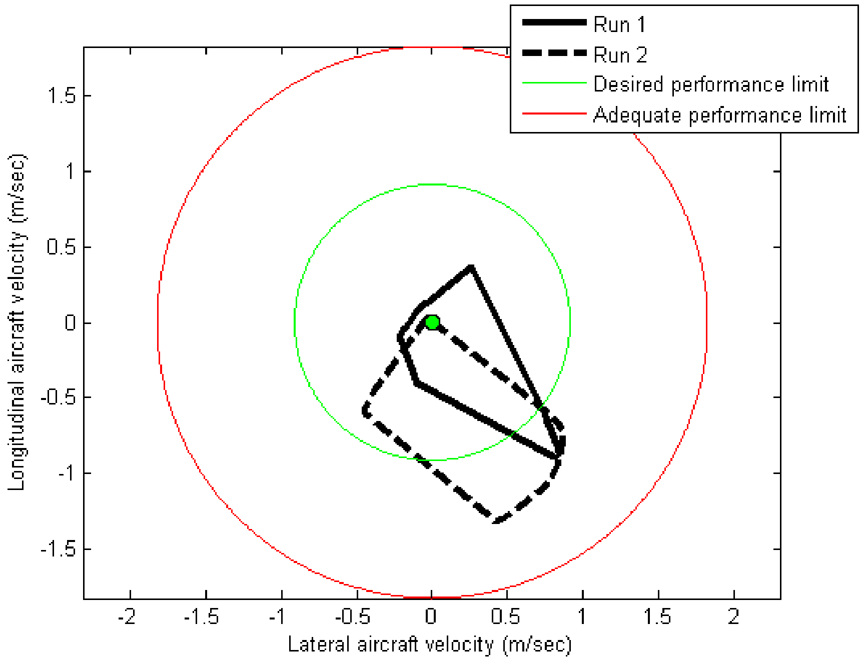


Figure 115 Maximum aircraft drift rate during MH1 using DVR strategy, Pilot 2

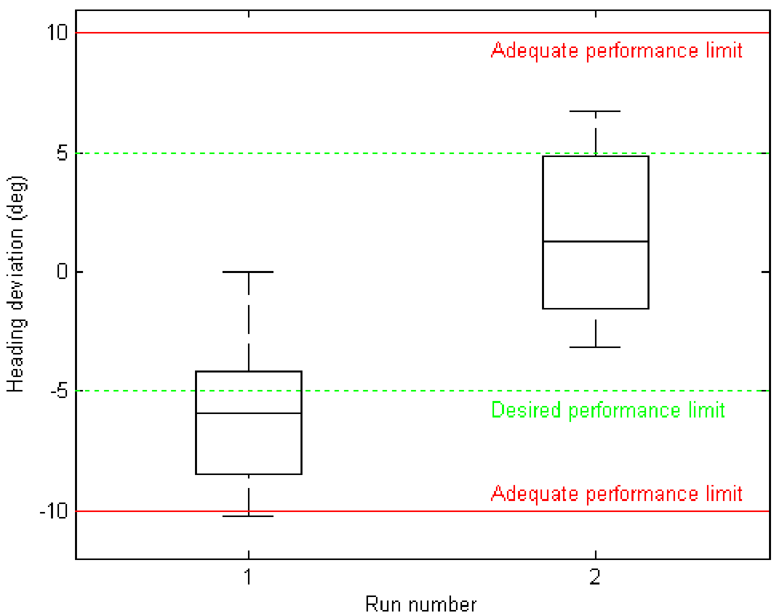


Figure 116 Maximum deviation of aircraft heading during MH1 using DVR strategy, Pilot 2

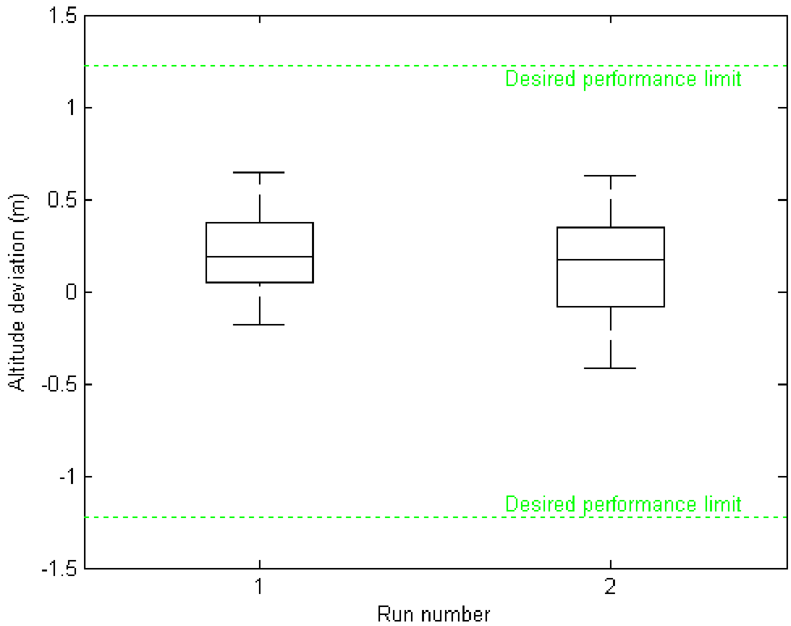


Figure 117 Maximum deviation of aircraft altitude during MH1 using DVR strategy, Pilot 2

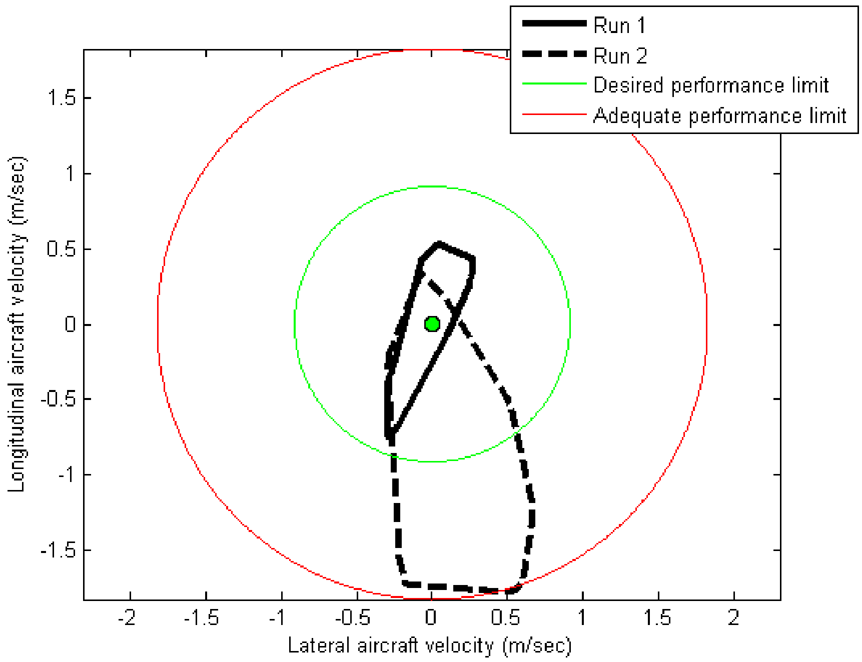


Figure 118 Maximum aircraft drift rate during MH1 using Boresighting reference strategy, Pilot 2

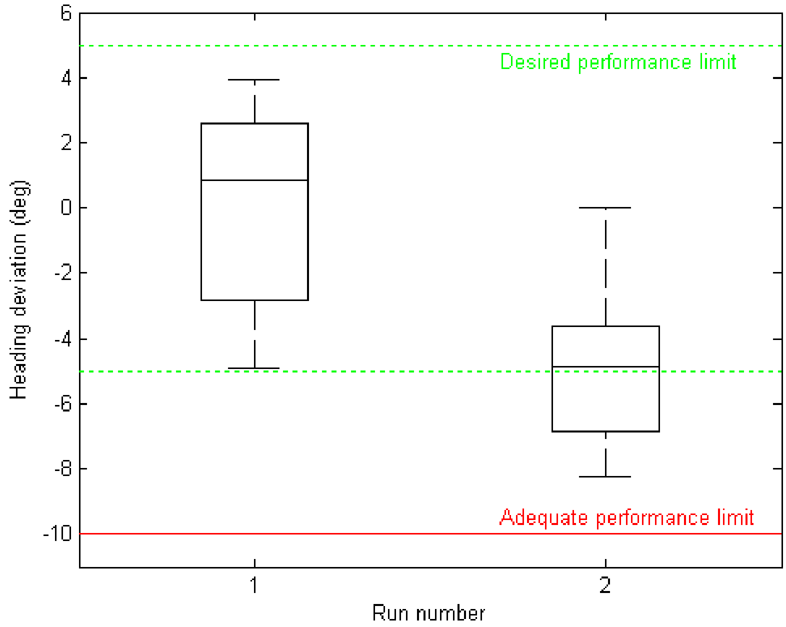


Figure 119 *Maximum deviation of aircraft heading during MH1 using Boresighting reference strategy, Pilot 2*

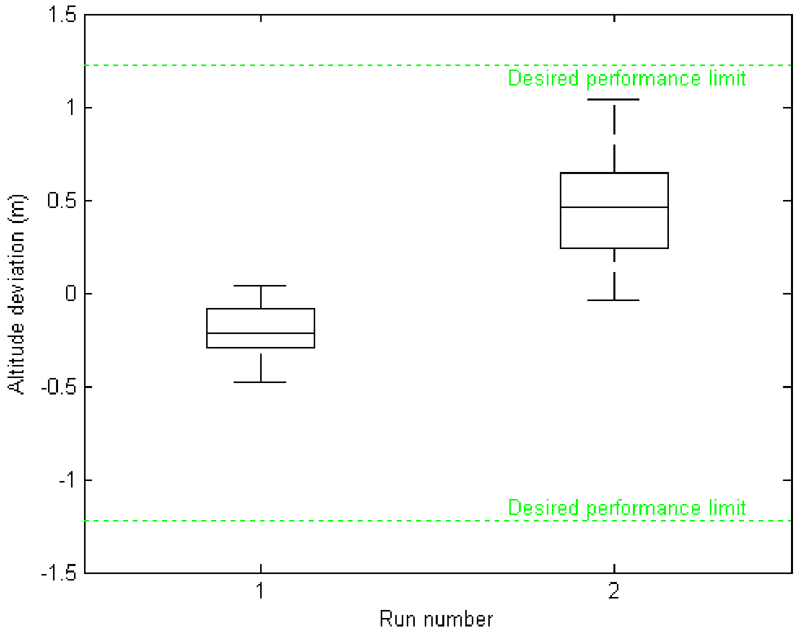


Figure 120 *Maximum deviation of aircraft altitude during MH1 using Boresighting reference strategy, Pilot 2*

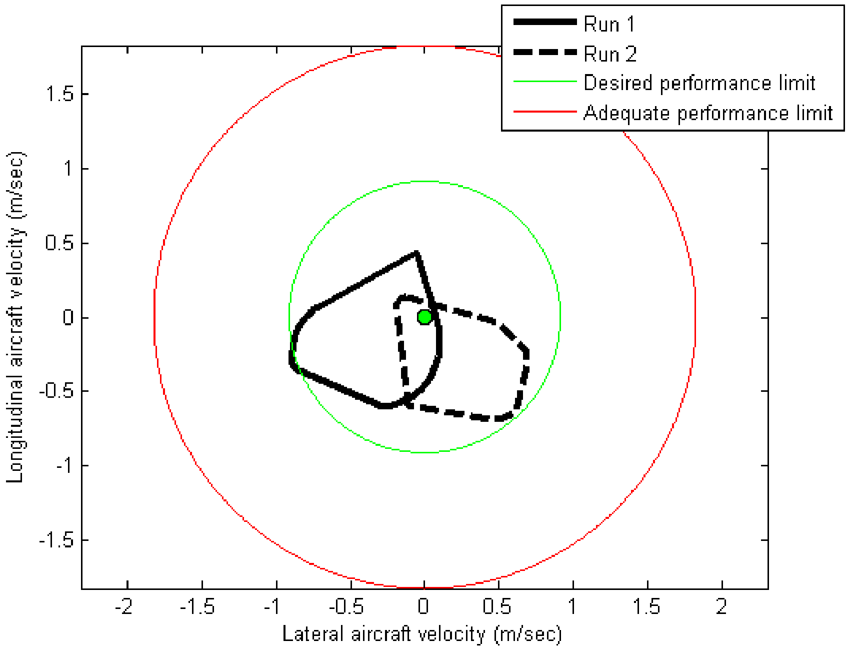


Figure 121 Maximum aircraft drift rate during MH1 using DVR strategy, Pilot 3

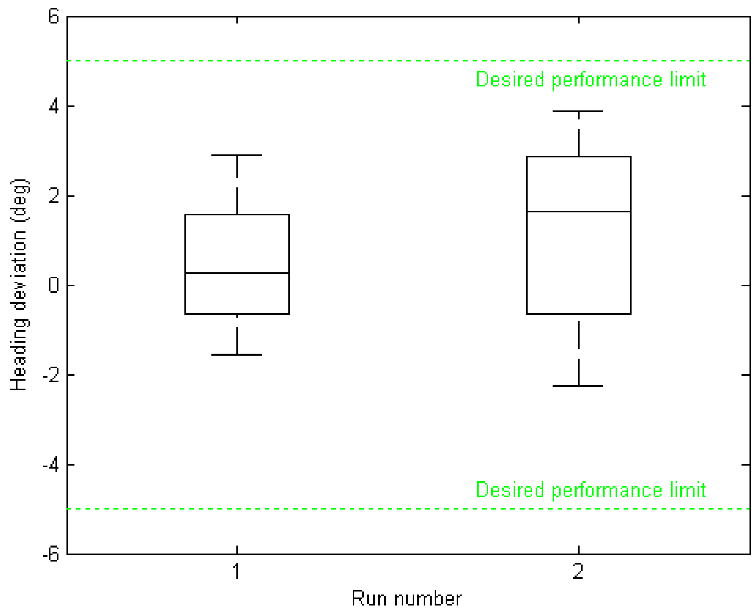


Figure 122 Maximum deviation of aircraft heading during MH1 using DVR strategy, Pilot 3

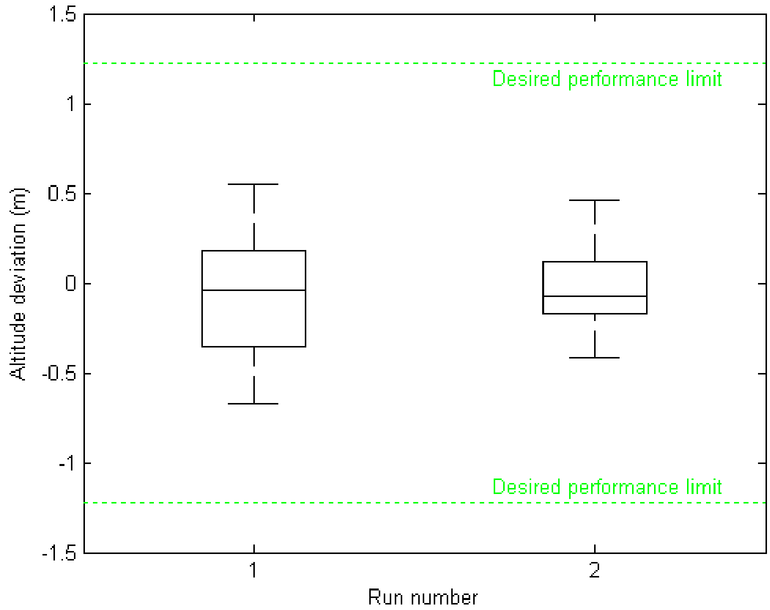


Figure 123 Maximum deviation of aircraft altitude during MH1 using DVR strategy, Pilot 3

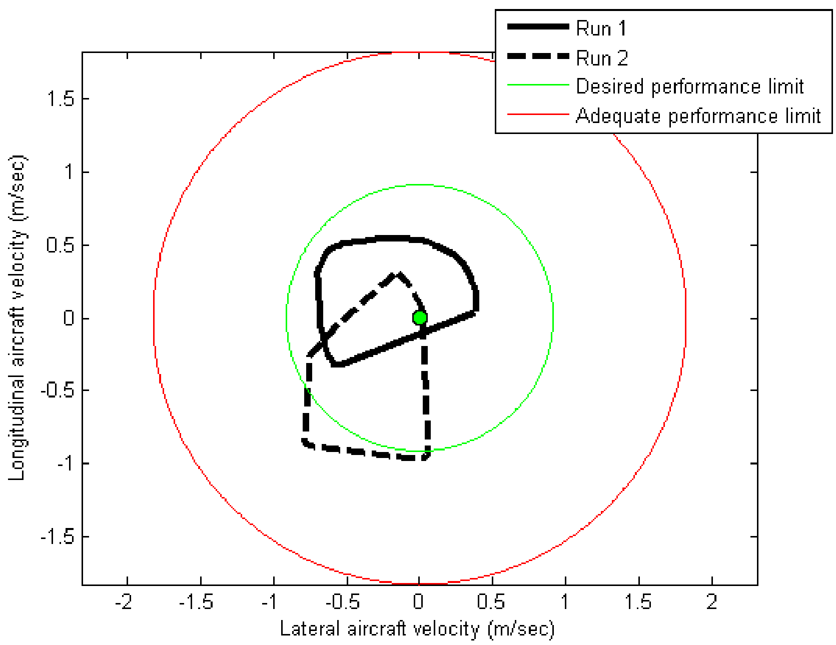


Figure 124 Maximum aircraft drift rate during MH1 using Boresighting reference strategy, Pilot 3

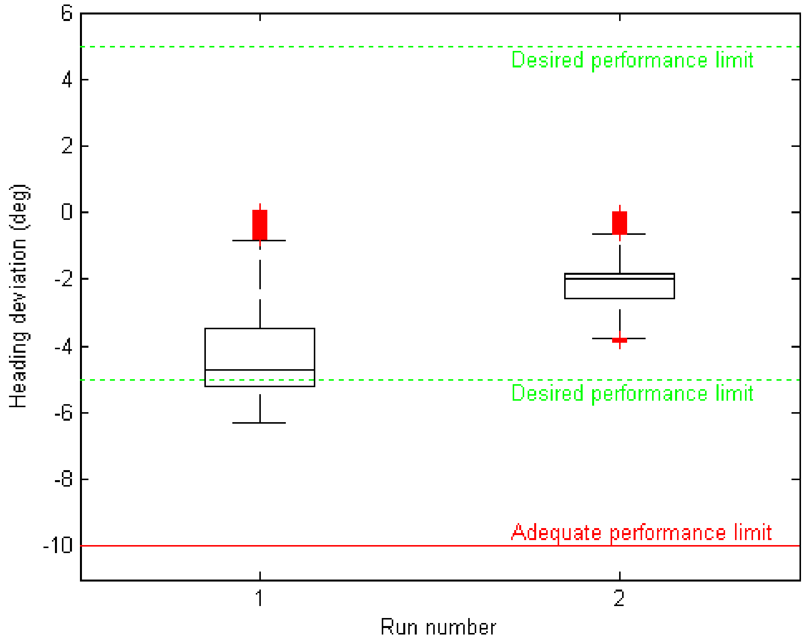


Figure 125 Maximum deviation of aircraft heading during MH1 using Boresighting reference strategy, Pilot 3

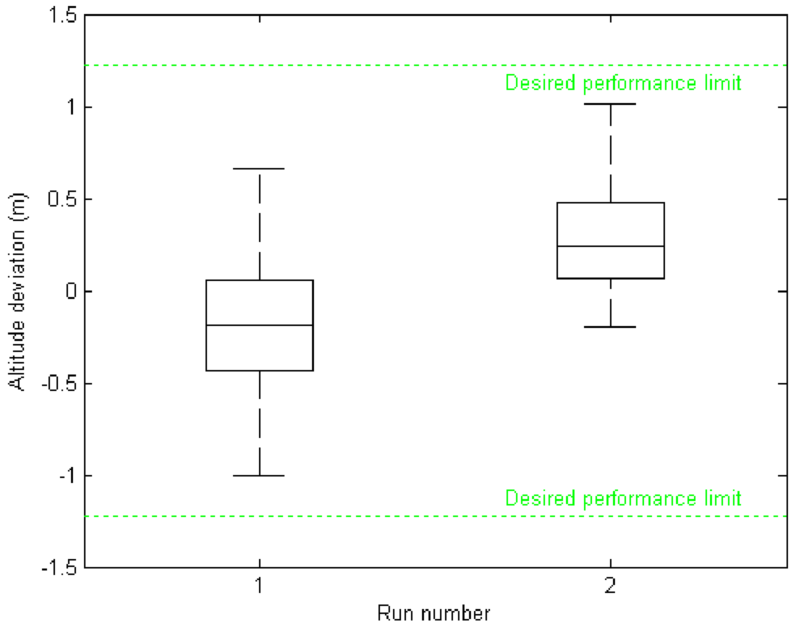


Figure 126 Maximum deviation of aircraft altitude during MH1 using Boresighting reference strategy, Pilot 3

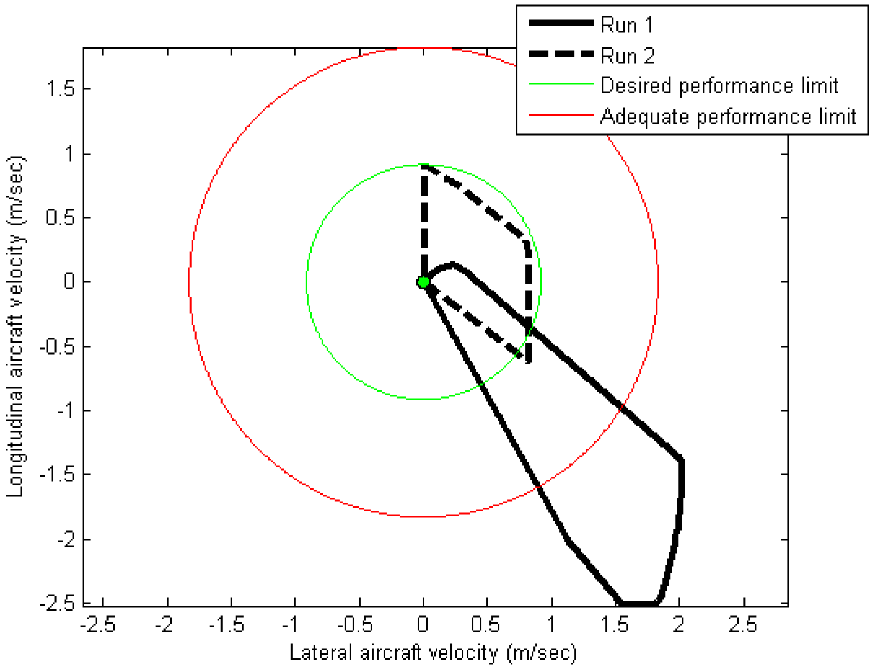


Figure 127 Maximum aircraft drift rate during MH1 using DVR strategy, Pilot 4

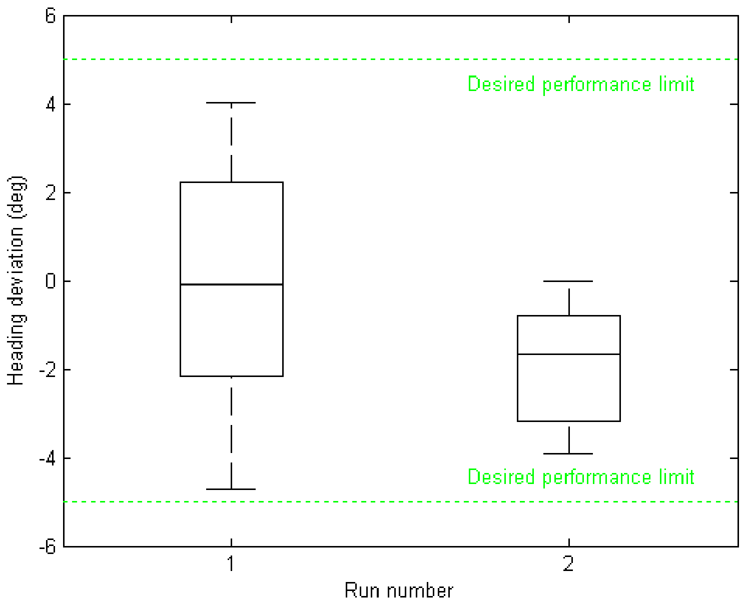


Figure 128 Maximum deviation of aircraft heading during MH1 using DVR strategy, Pilot 4

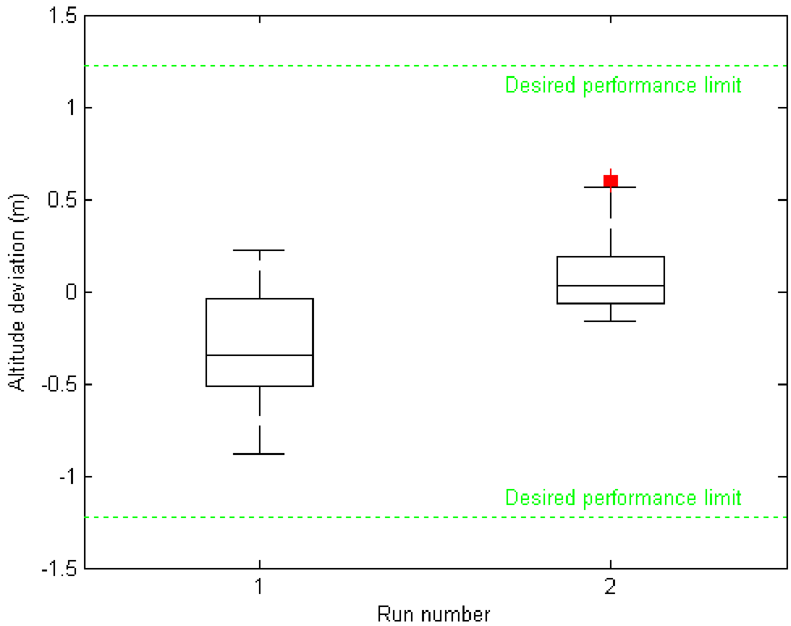


Figure 129 Maximum deviation of aircraft altitude during MH1 using DVR strategy, Pilot 4

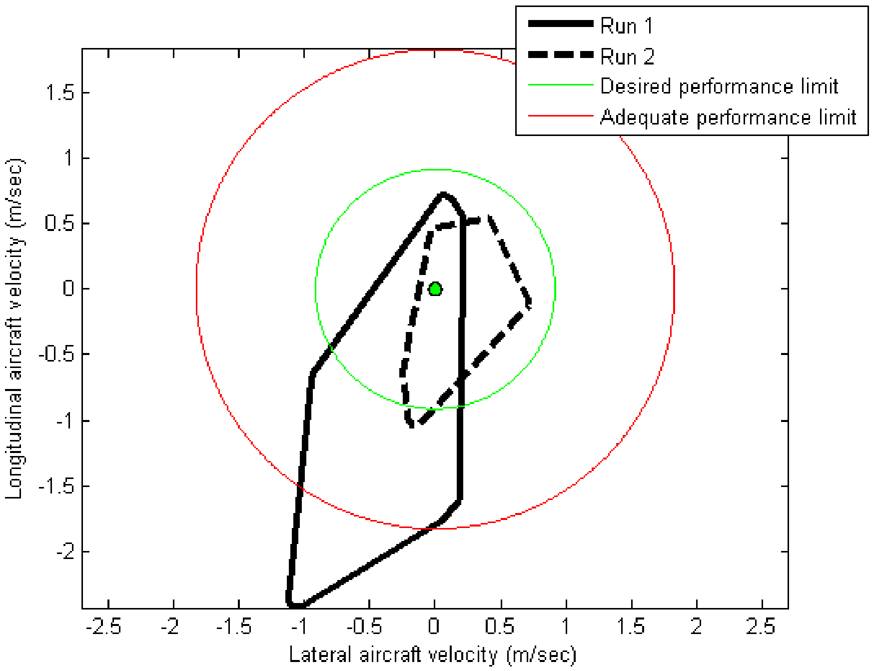


Figure 130 Maximum aircraft drift rate during MH1 using Boresighting reference strategy, Pilot 3

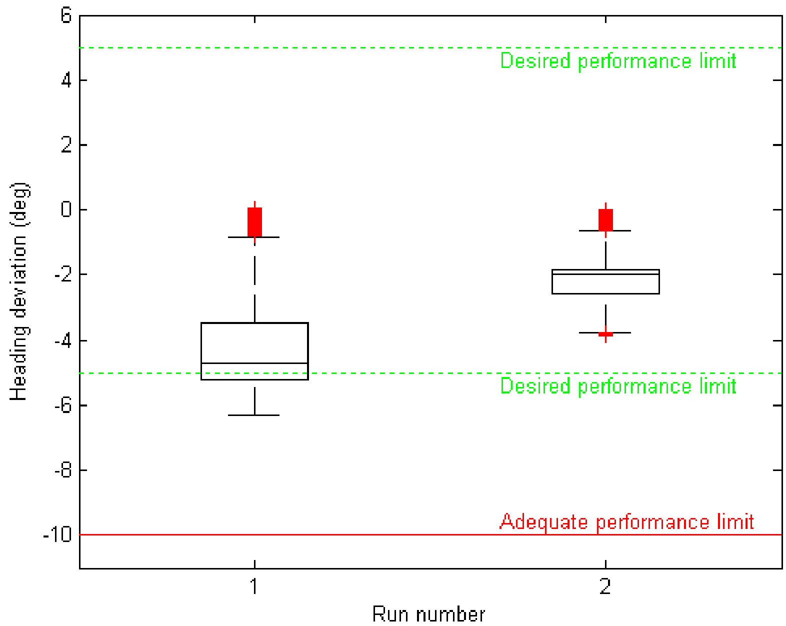


Figure 131 Maximum deviation of aircraft heading during MH1 using Boresighting reference strategy, Pilot 4

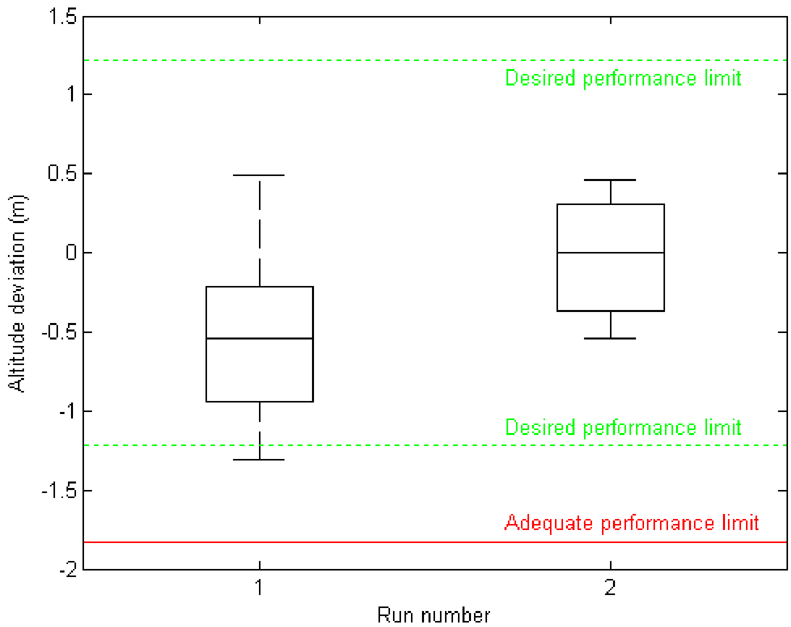


Figure 132 Maximum deviation of aircraft altitude during MH1 using Boresighting reference strategy, Pilot 4

F.4 Maritime Hover Manoeuvre, Moderate Seas (MH2)

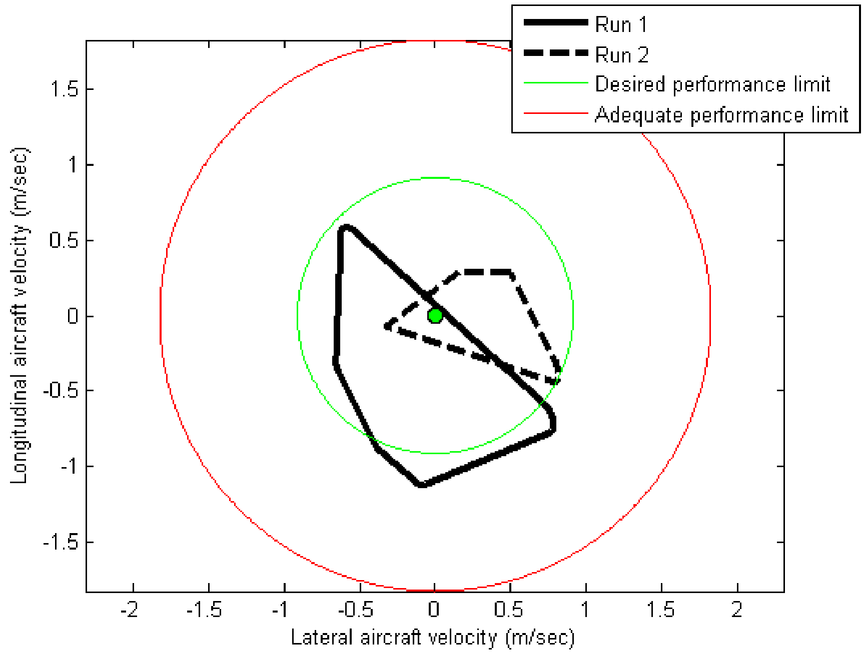


Figure 133 Maximum aircraft drift rate during MH2 using DVR strategy, Pilot 2

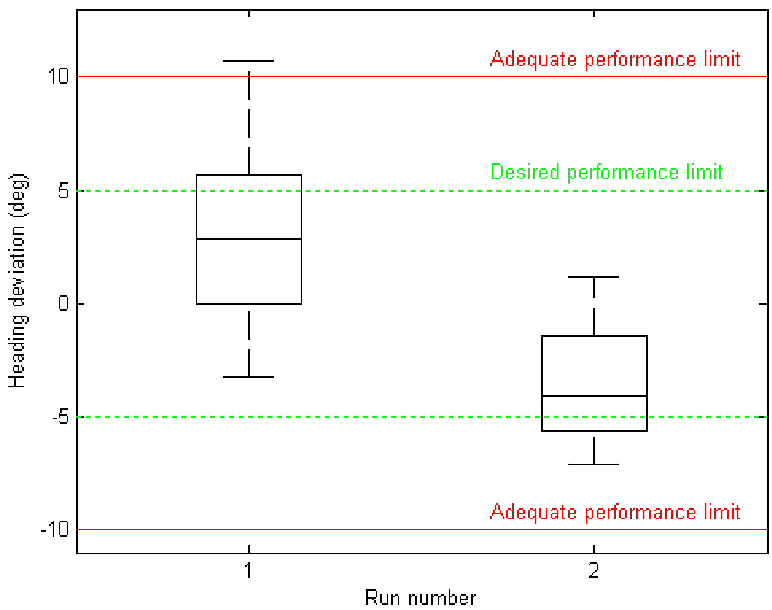


Figure 134 Maximum deviation of aircraft heading during MH2 using DVR strategy, Pilot 2

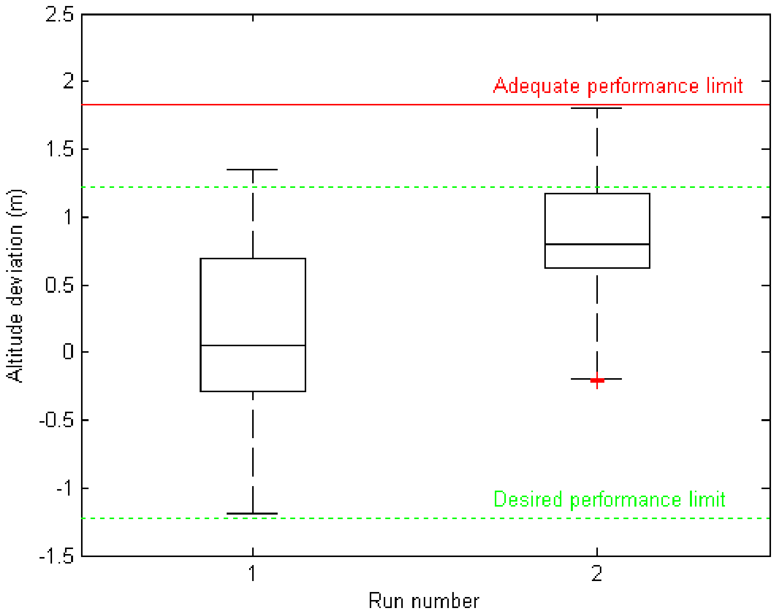


Figure 135 Maximum deviation of aircraft altitude during MH2 using DVR strategy, Pilot 2

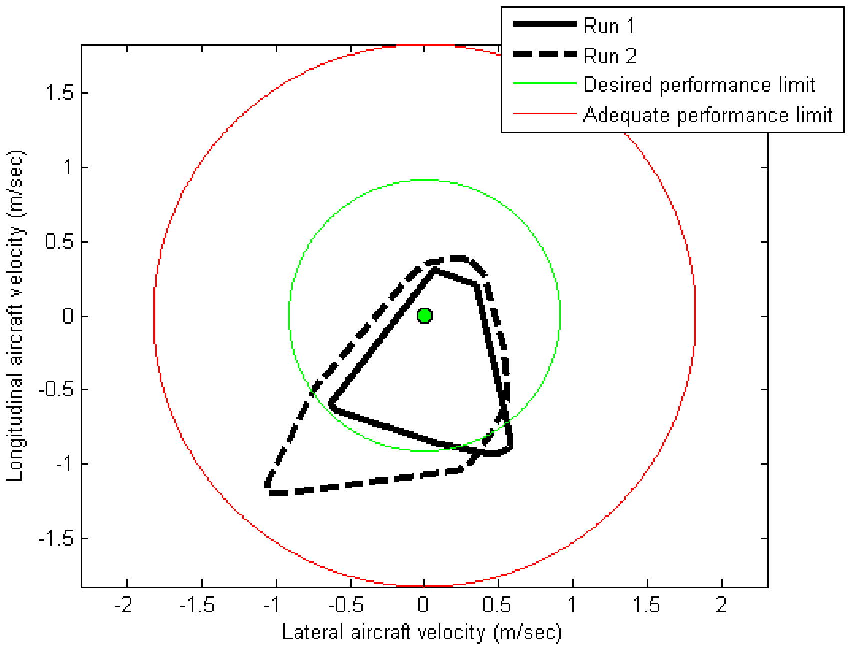


Figure 136 Maximum aircraft drift rate during MH2 using Boresighting reference strategy, Pilot 2

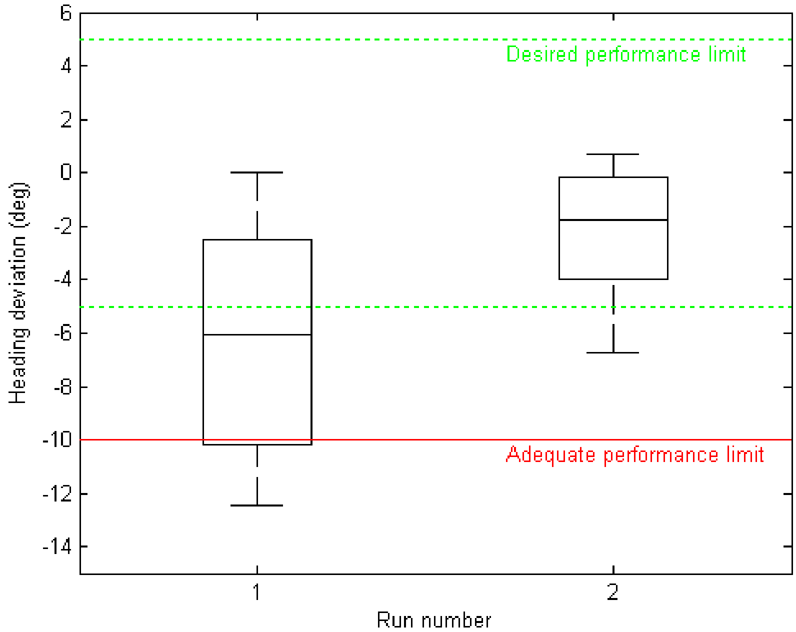
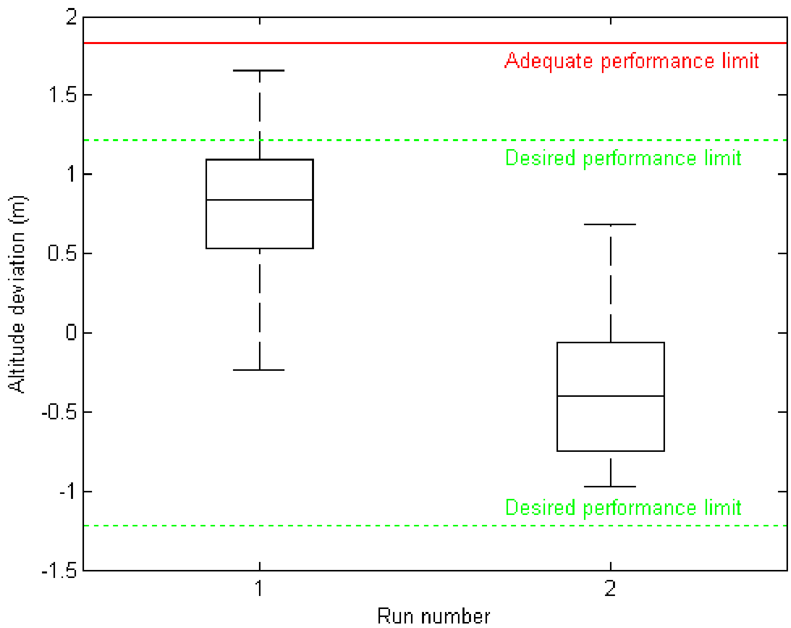


Figure 137 Maximum deviation of aircraft heading during MH2 using Boresighting reference strategy, Pilot 2



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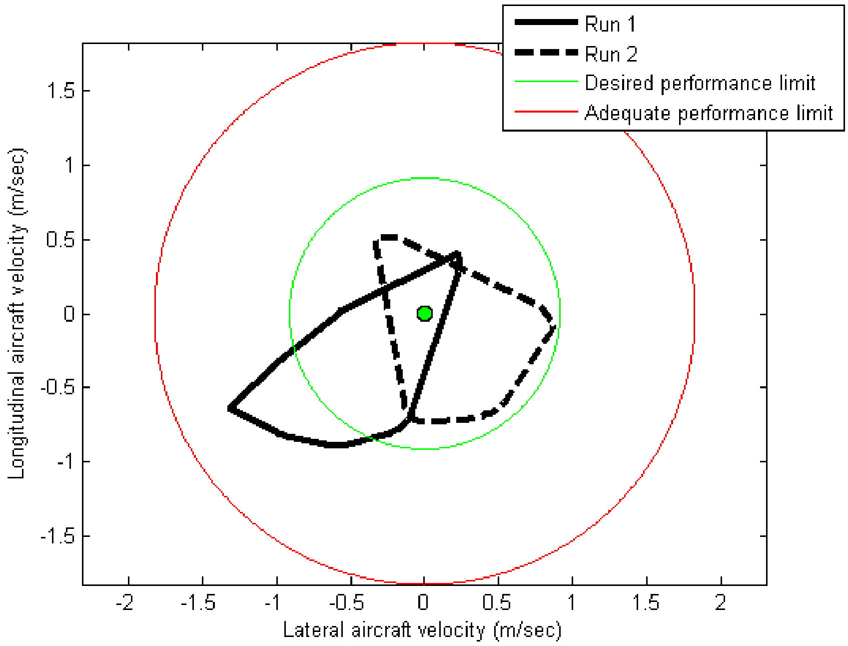

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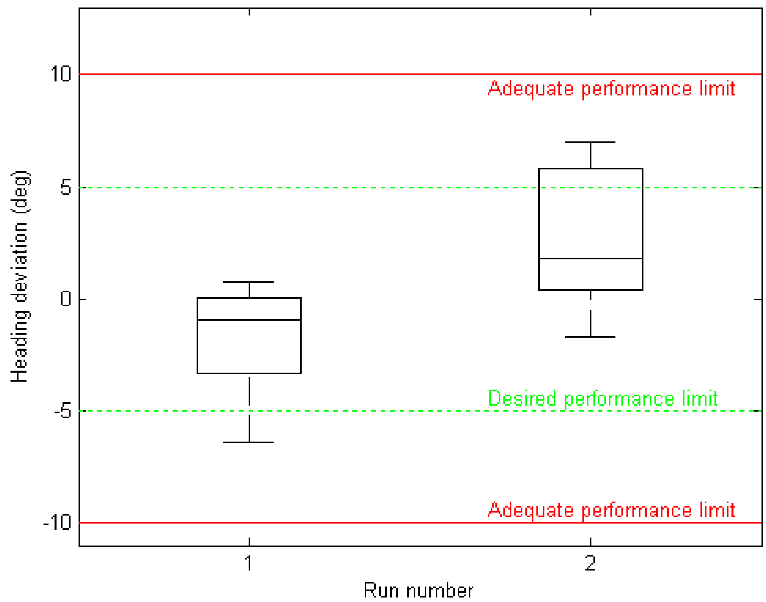


Figure 140 Maximum deviation of aircraft heading during MH2 using DVR strategy, Pilot 3

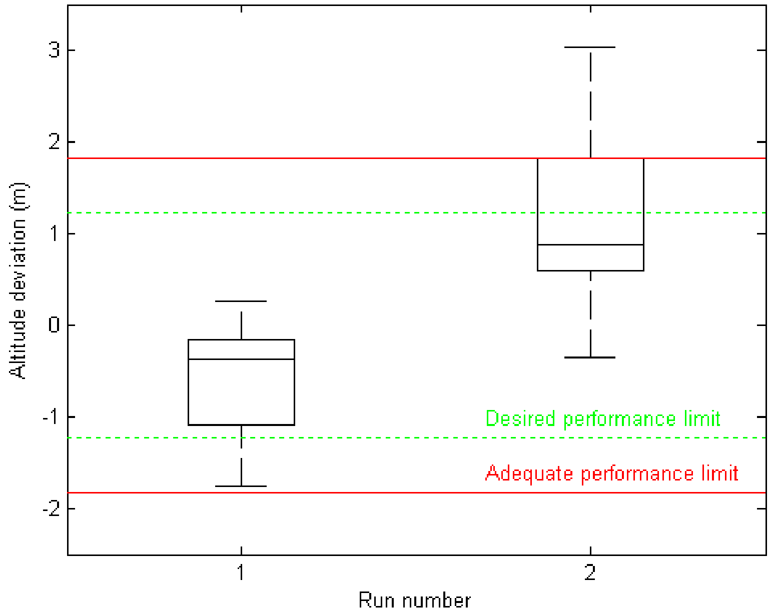


Figure 141   Maximum deviation of aircraft altitude during MH2 using DVR strategy, Pilot 3

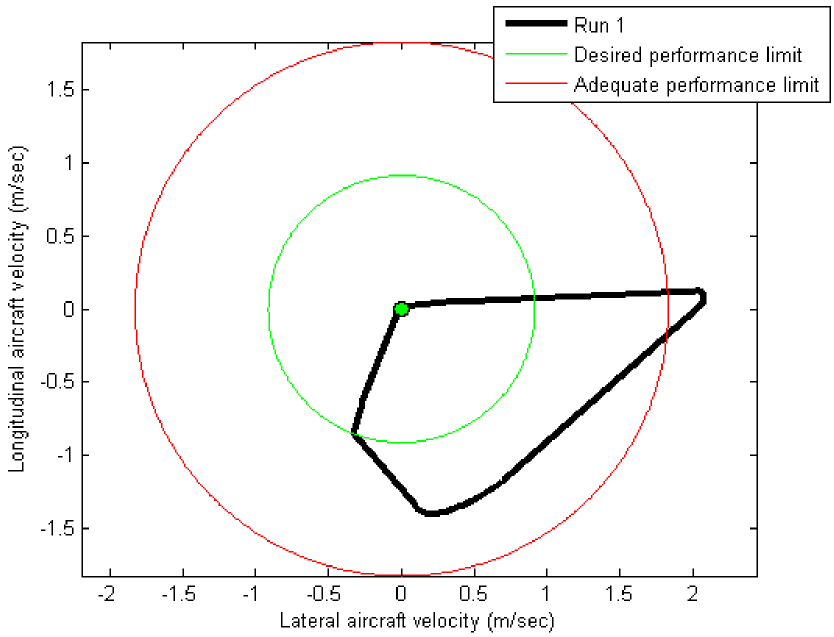


Figure 142   Maximum aircraft drift rate during MH2 using Boresighting reference strategy, Pilot 3

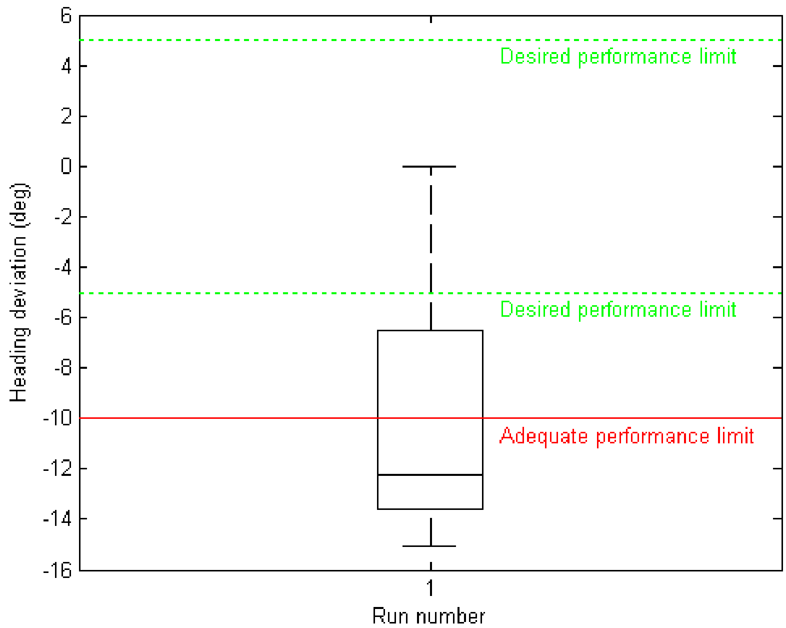


Figure 143 *Maximum deviation of aircraft heading during MH2 using Boresighting reference strategy, Pilot 3*

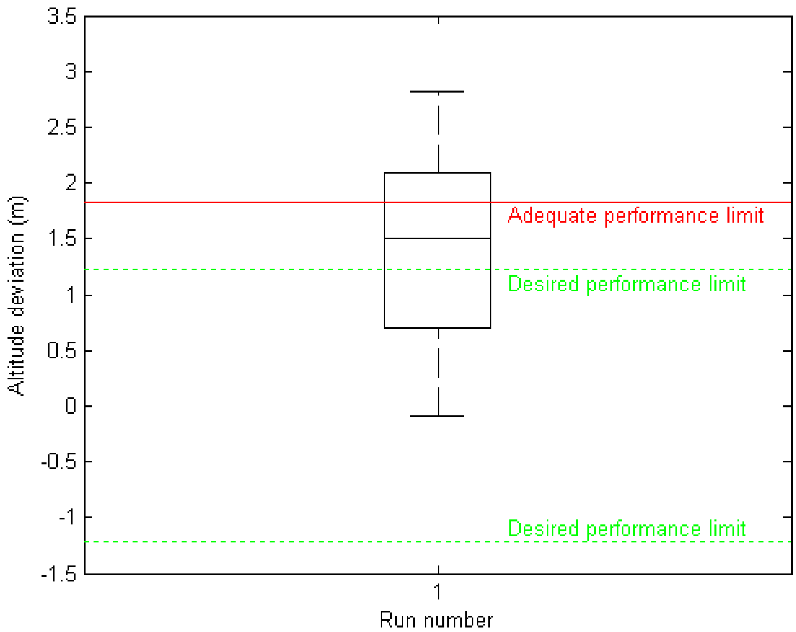


Figure 144 *Maximum deviation of aircraft altitude during MH2 using Boresighting reference strategy, Pilot 3*

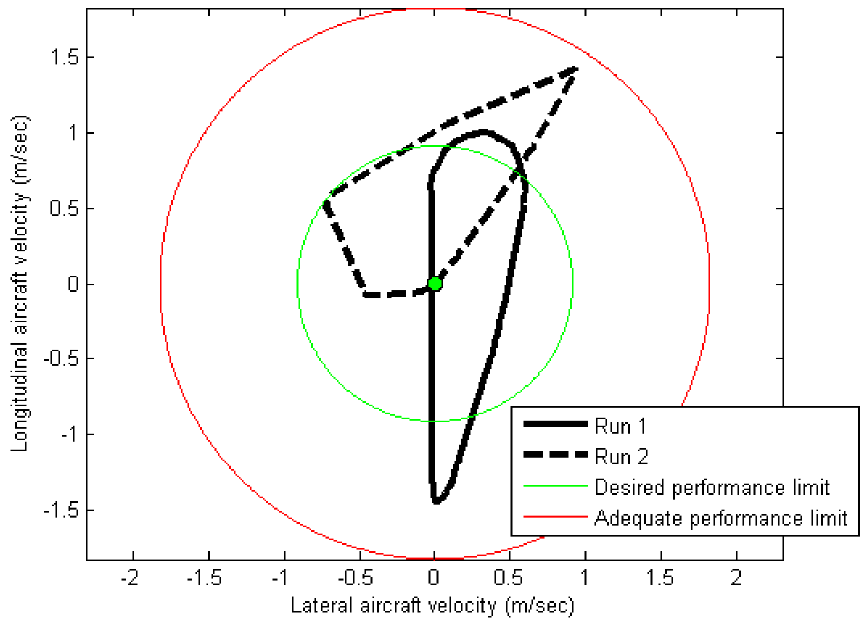


Figure 145 Maximum aircraft drift rate during MH2 using DVR strategy, Pilot 4

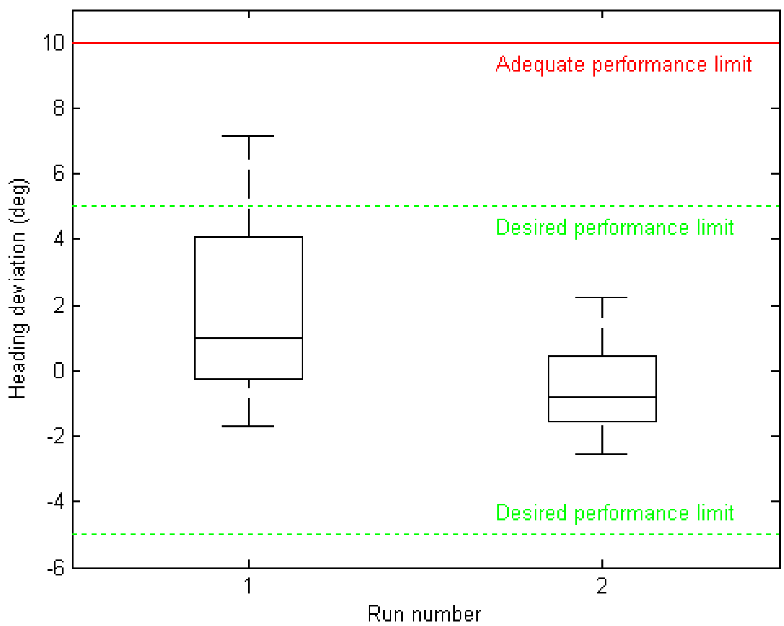


Figure 146 Maximum deviation of aircraft heading during MH2 using DVR strategy, Pilot 4

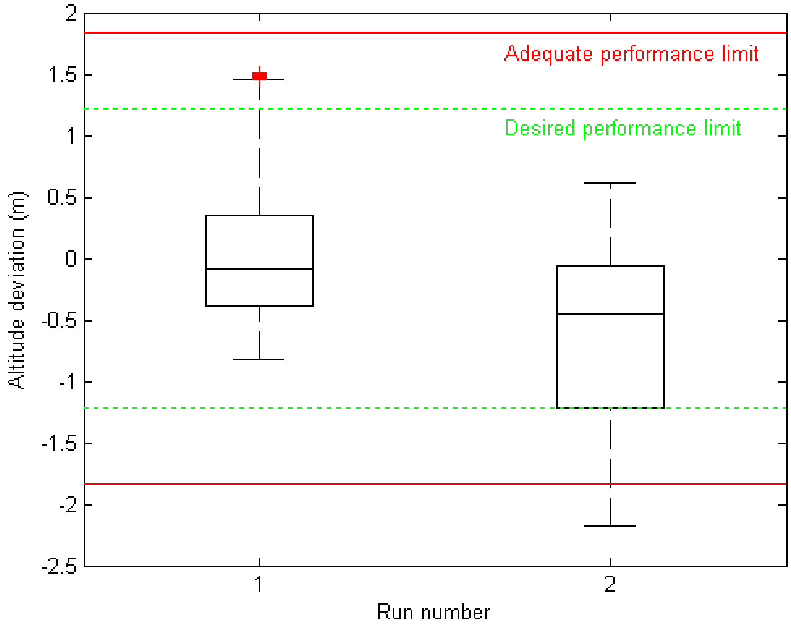


Figure 147   Maximum deviation of aircraft altitude during MH2 using DVR strategy, Pilot 4

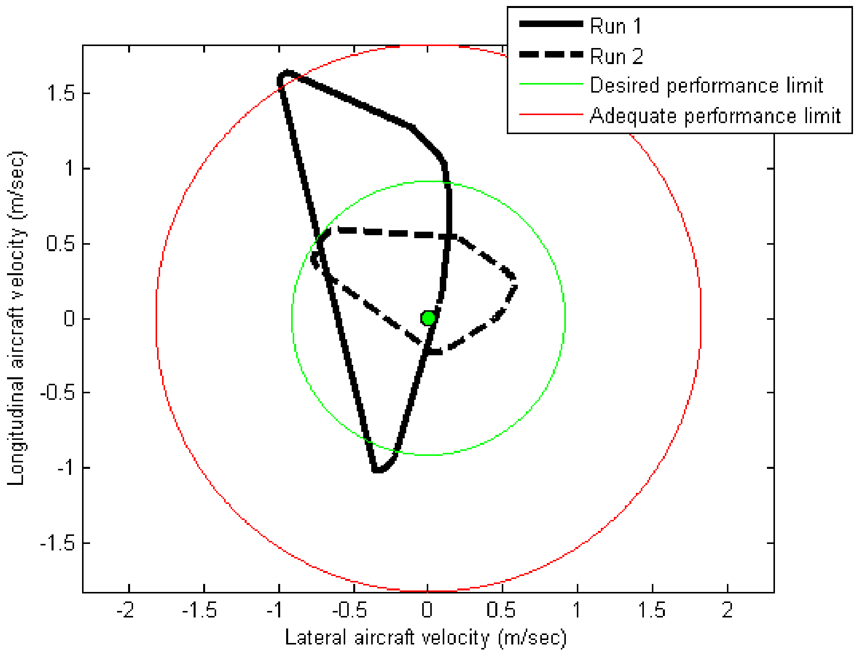
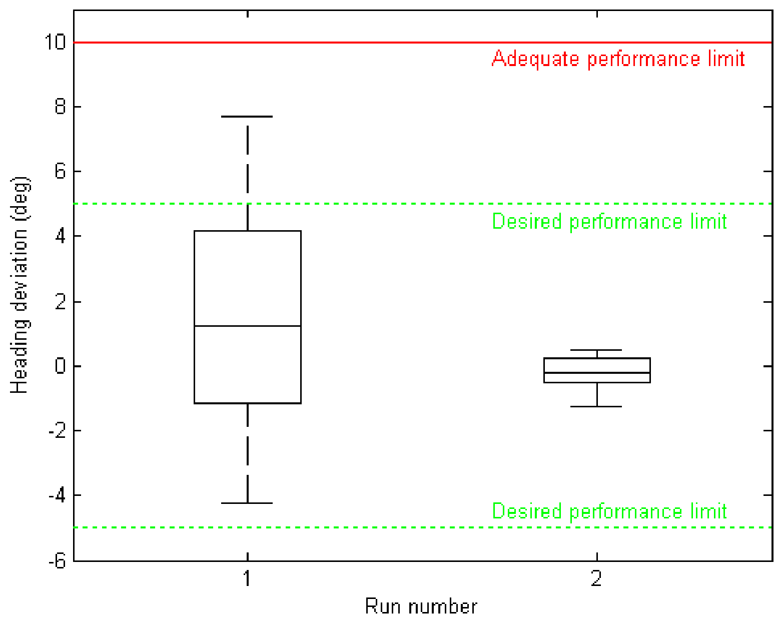


Figure 148   Maximum aircraft drift rate during MH2 using Boresighting reference strategy, Pilot 4



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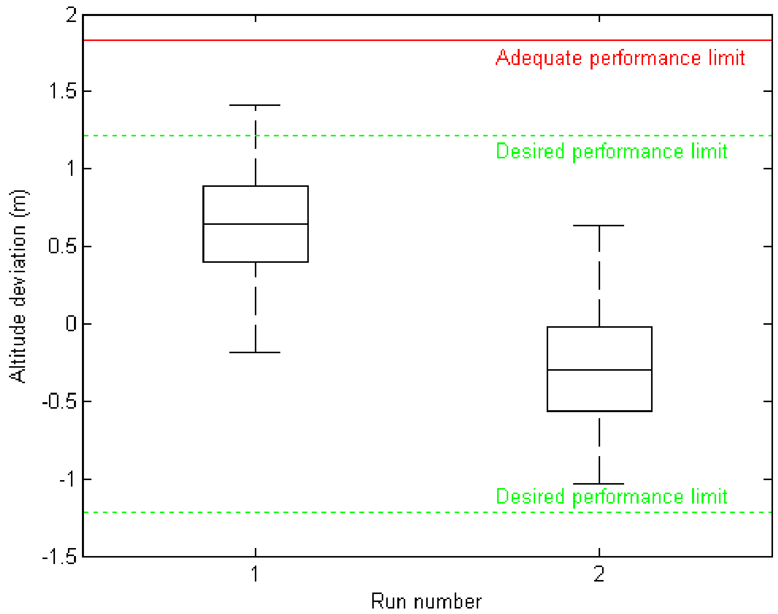


Figure 150 Maximum deviation of aircraft altitude during MH2 using Boresighting reference strategy, Pilot 4

F.5 Maritime Hover Manoeuvre, Rough Seas (MH3)

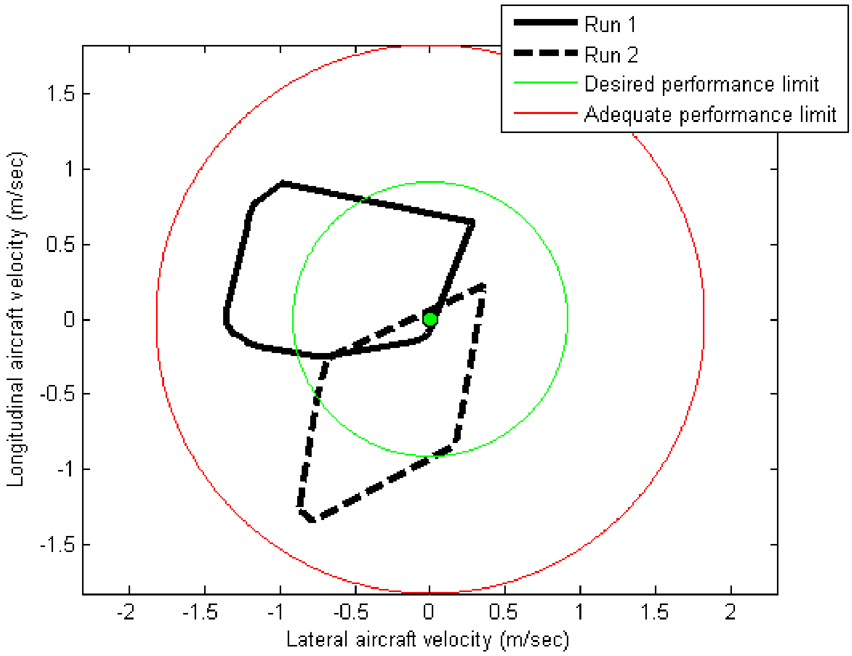


Figure 151 Maximum aircraft drift rate during MH3 using DVR strategy, Pilot 2

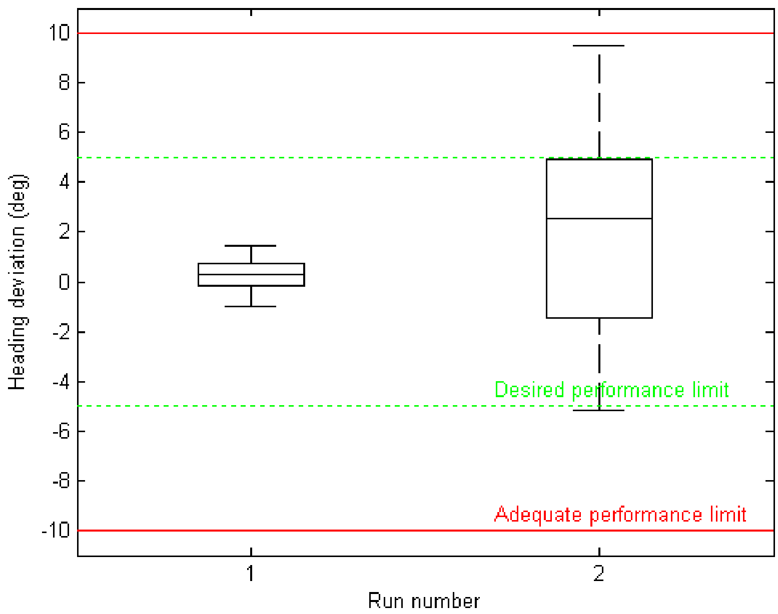


Figure 152 Maximum deviation of aircraft heading during MH3 using DVR strategy, Pilot 2

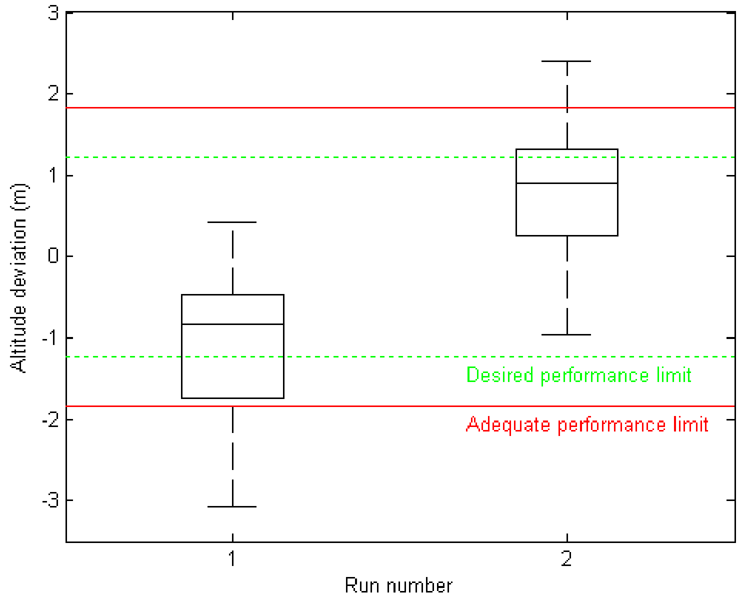


Figure 153 Maximum deviation of aircraft altitude during MH3 using DVR strategy, Pilot 2

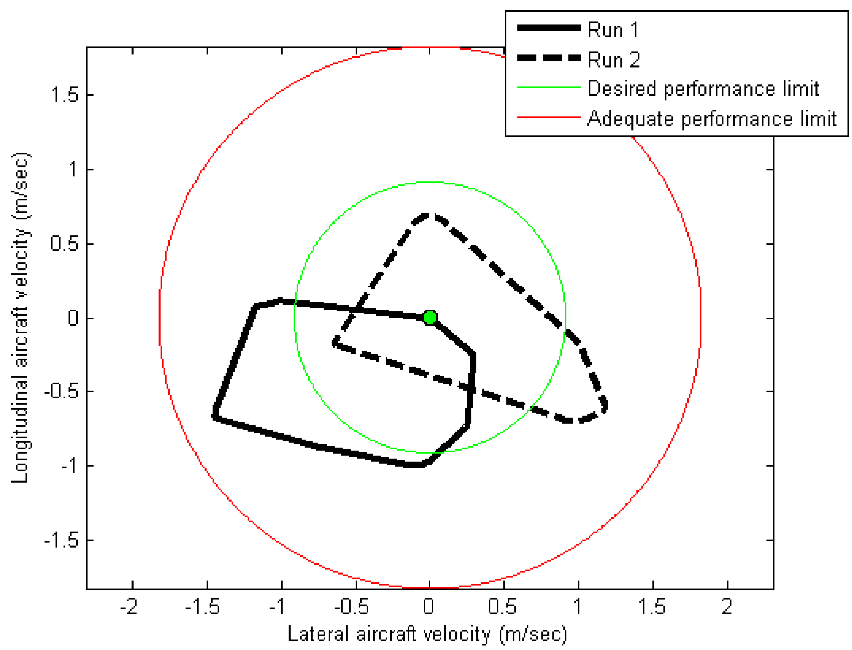


Figure 154 Maximum aircraft drift rate during MH3 using Boresighting reference strategy, Pilot 2

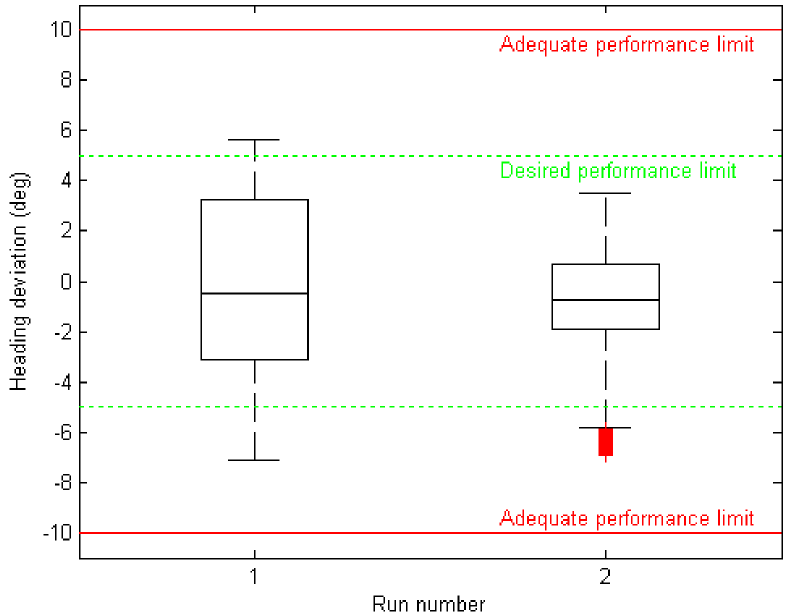


Figure 155 Maximum deviation of aircraft heading during MH3 using Boresighting reference strategy, Pilot 2

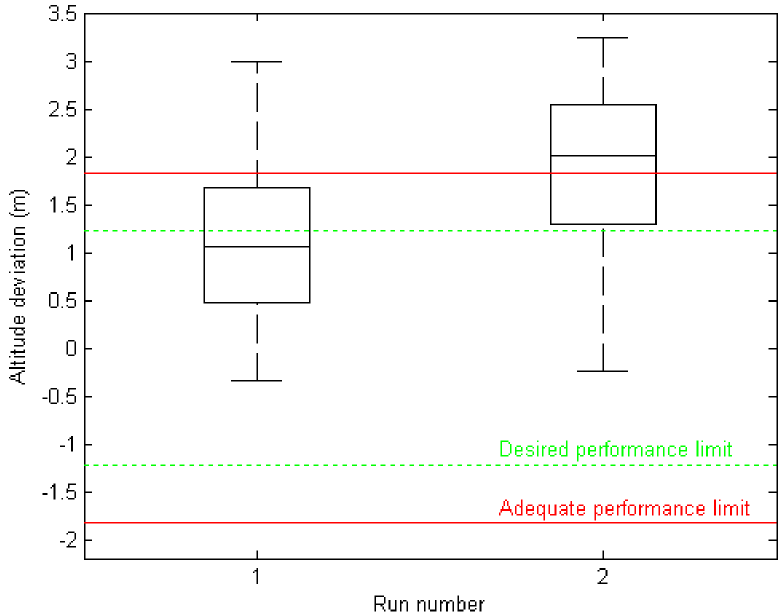


Figure 156 Maximum deviation of aircraft altitude during MH3 using Boresighting reference strategy, Pilot 2

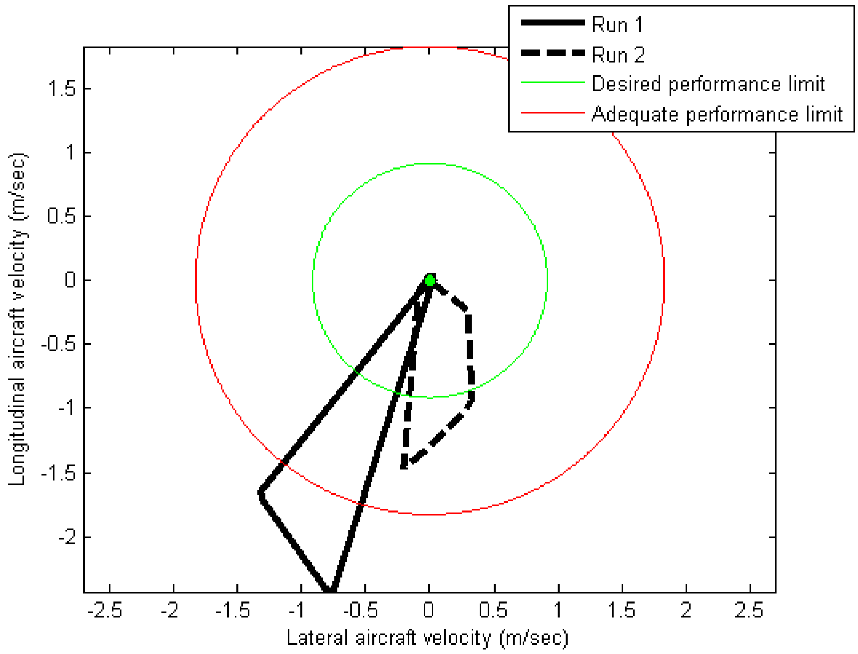


Figure 157 Maximum aircraft drift rate during MH3 using DVR strategy, Pilot 3

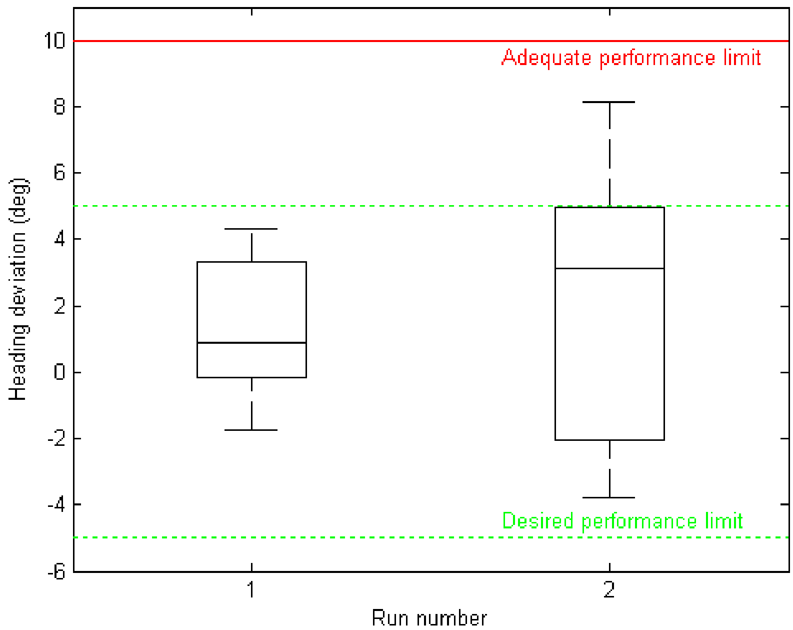


Figure 158 Maximum deviation of aircraft heading during MH3 using DVR strategy, Pilot 3

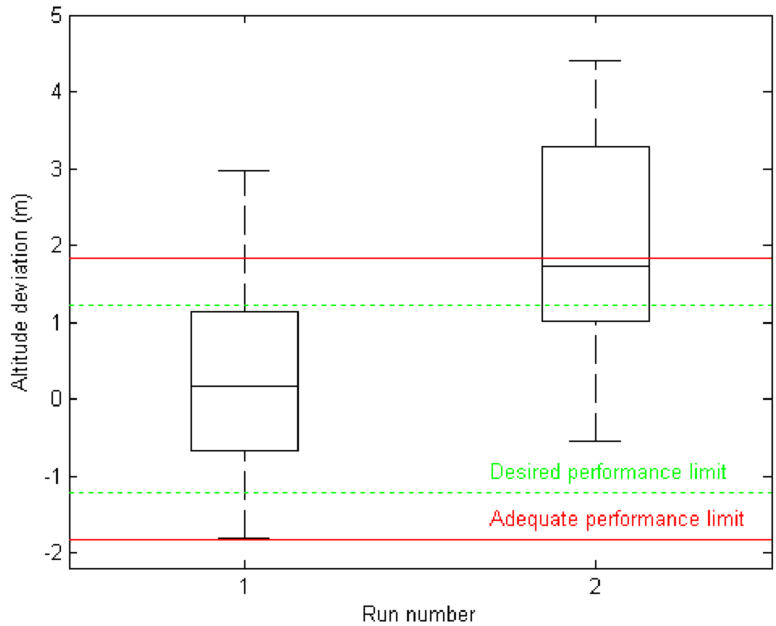
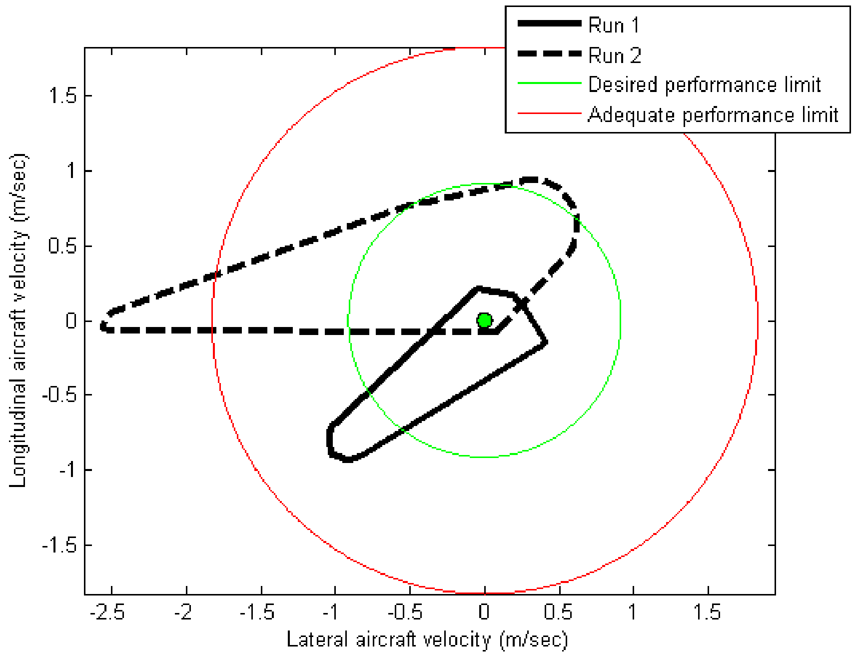


Figure 159 Maximum deviation of aircraft altitude during MH3 using DVR strategy, Pilot 3



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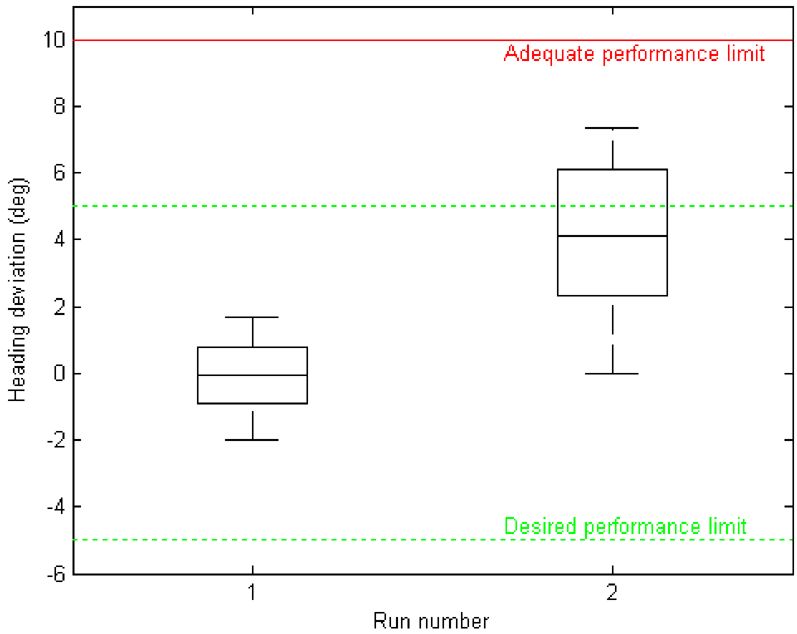

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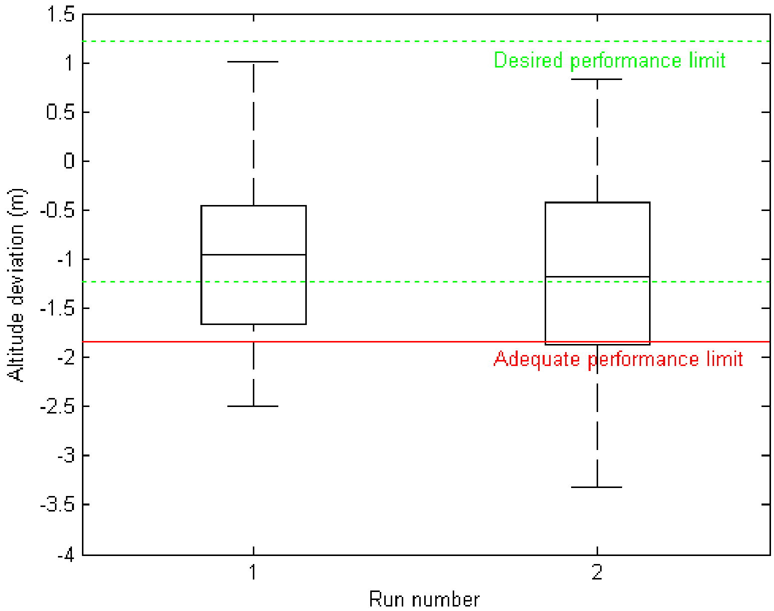

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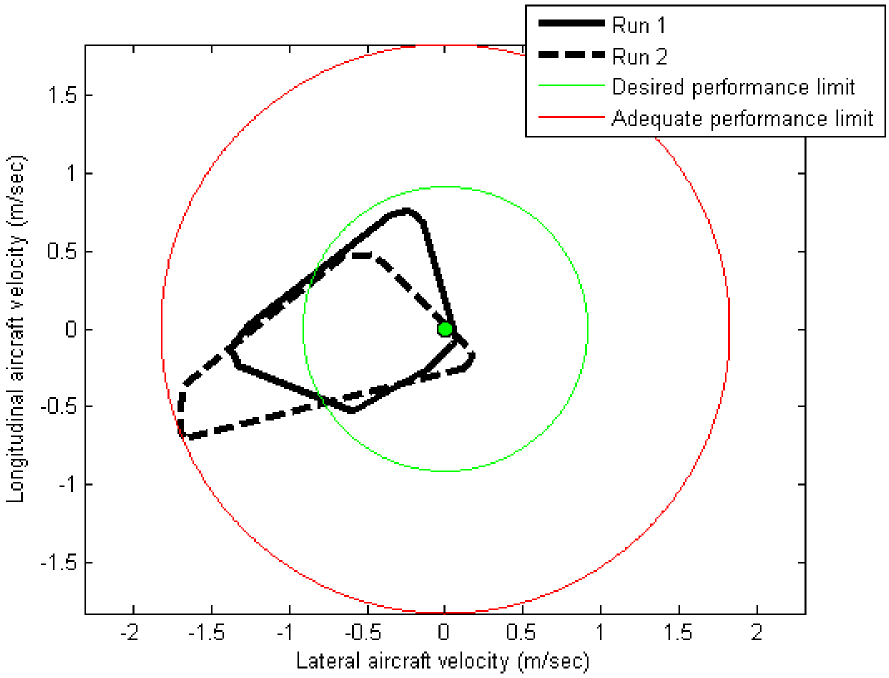
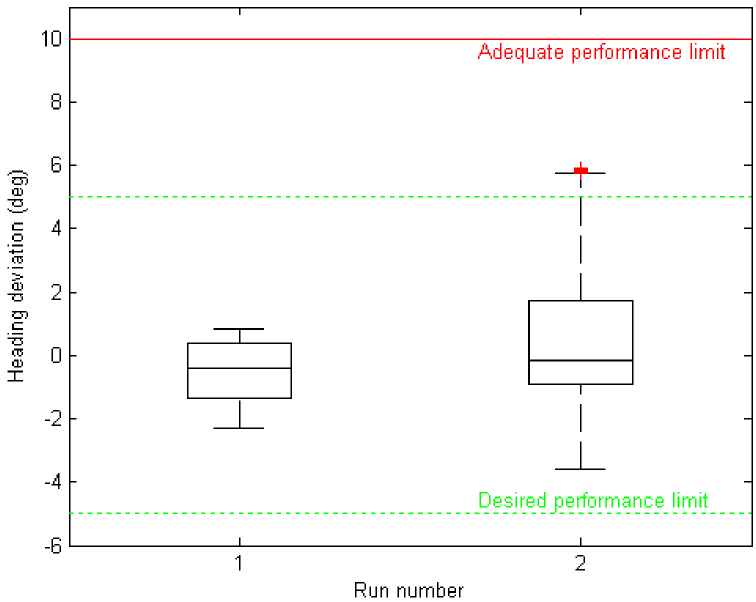


Figure 163   Maximum aircraft drift rate during MH3 using DVR strategy, Pilot 4



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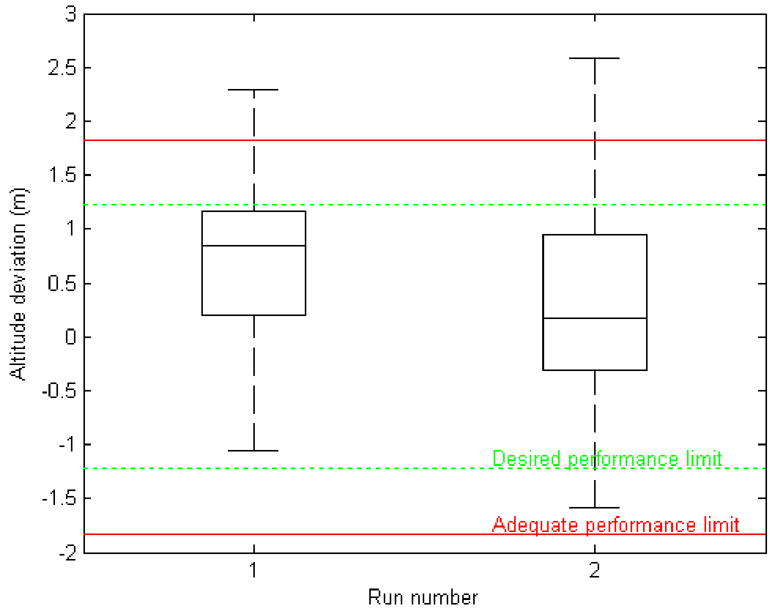

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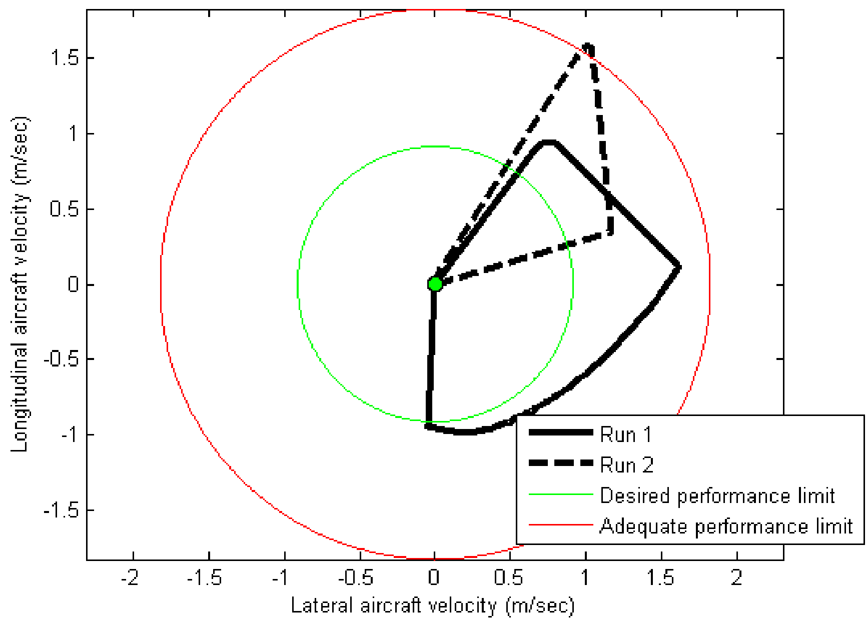

Figure 166 Maximum aircraft drift rate during MH3 using Boresighting reference strategy, Pilot 4

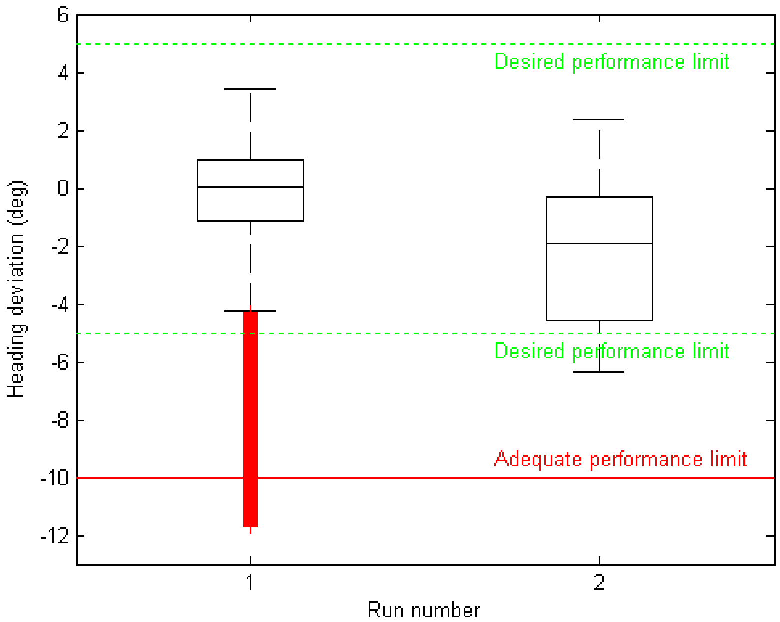

Figure 167 Maximum deviation of aircraft heading during MH3 using Boresighting reference strategy, Pilot 4

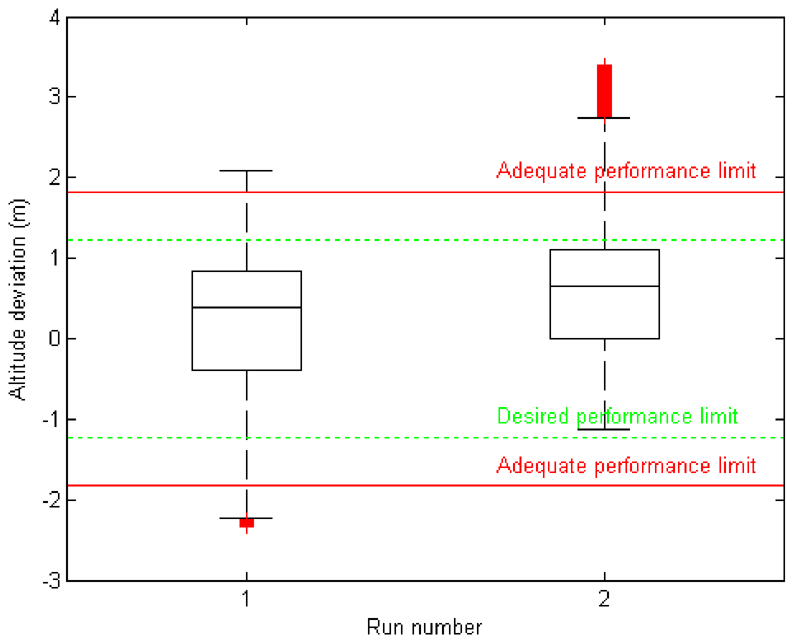

Figure 168 Maximum deviation of aircraft altitude during MH3 using Boresighting reference strategy, Pilot 4

Appendix G: Off-Course Ground Hover, AS350B Squirrel Flight Model

G.1 Ground Hover

The following results were obtained after pilots were asked to hold hover with respect to an arbitrary feature on the simulator airfield. No further cues were provided.

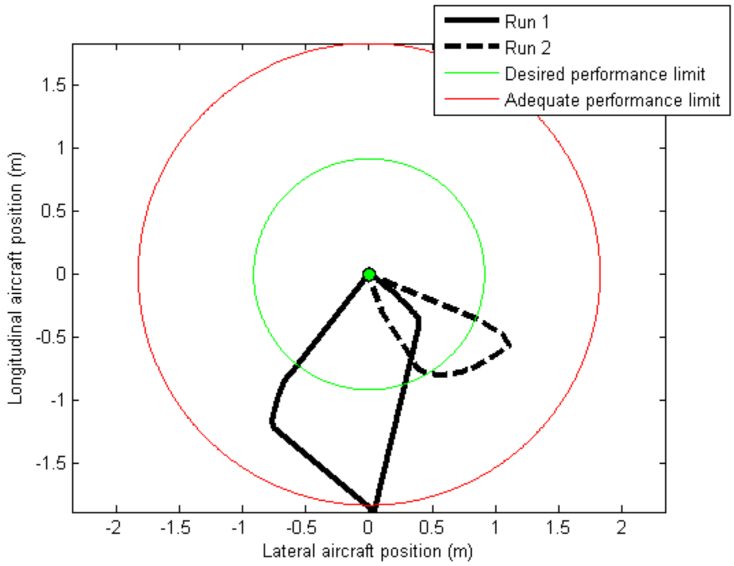

Figure 169 Maximum deviation of aircraft plan position during off-course ground hover, Pilot 2

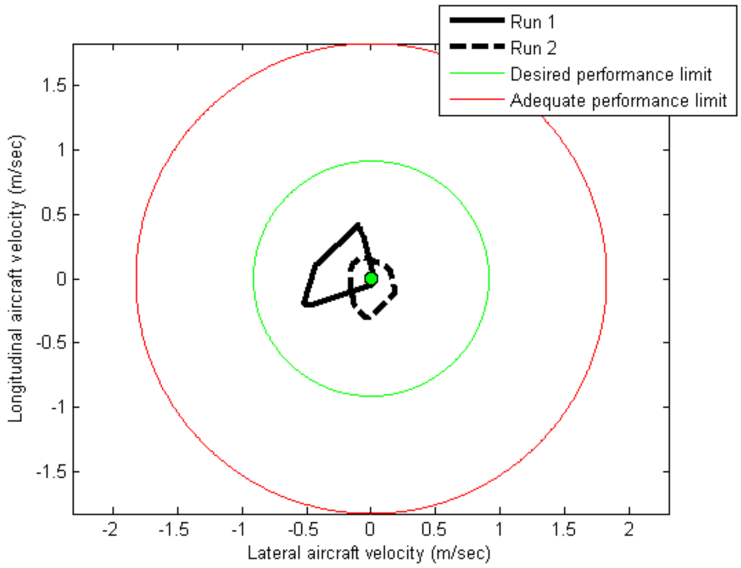

Figure 170 Maximum aircraft drift rate during off-course ground hover, Pilot 2

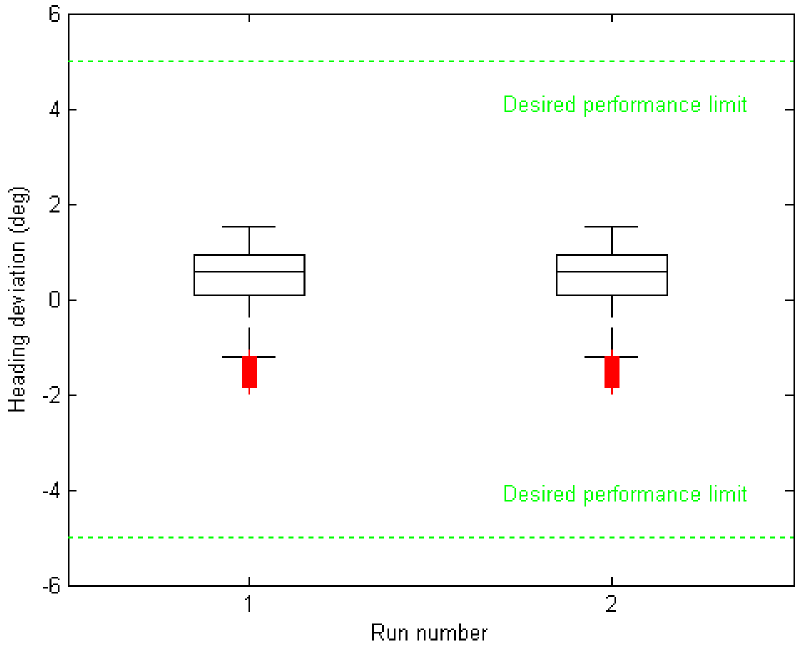

Figure 171 Maximum deviation of aircraft heading during off-course ground hover, Pilot 2

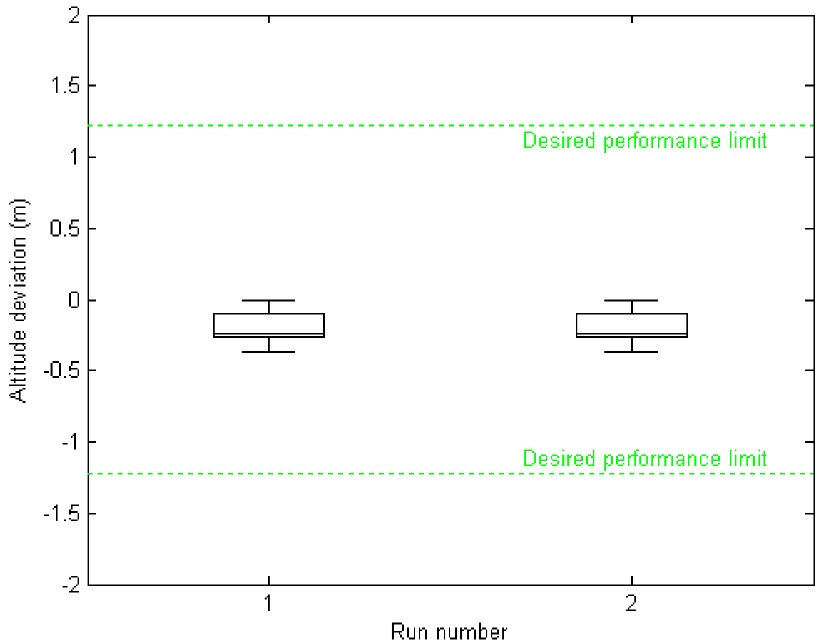

Figure 172 Maximum deviation of aircraft altitude during off-course ground hover, Pilot 2

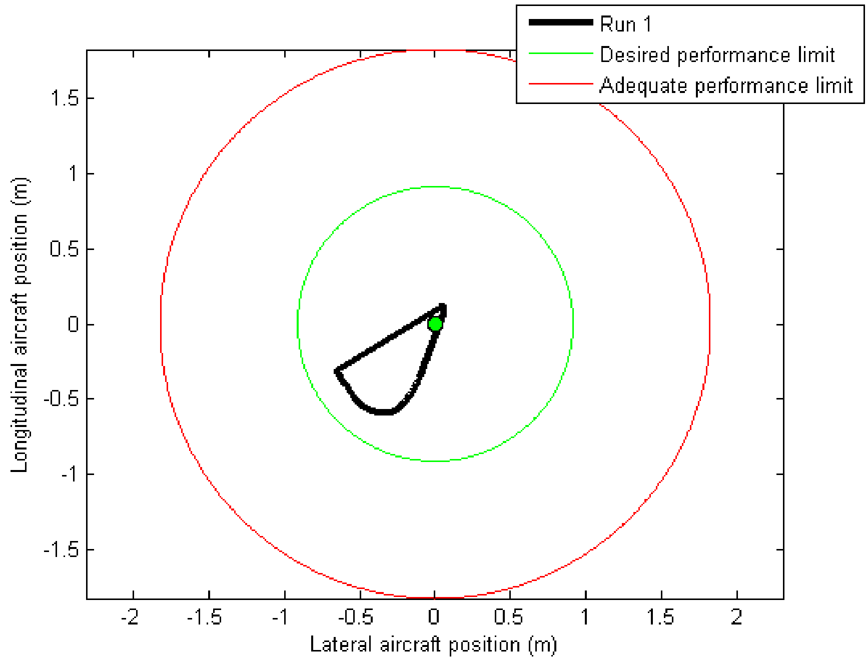

Figure 173 Maximum deviation of aircraft plan position during off-course ground hover, Pilot 3

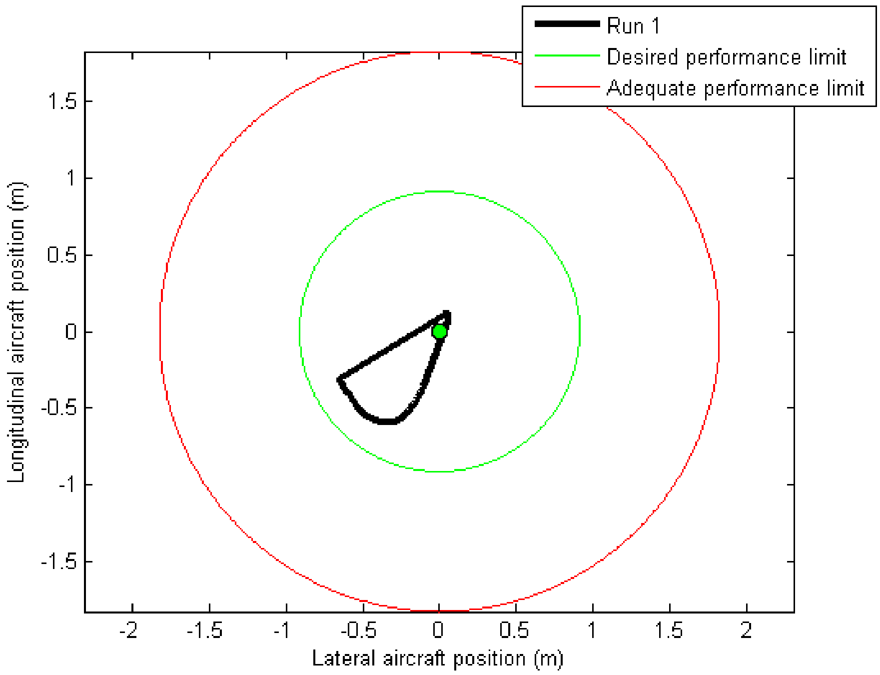

Figure 174 Maximum aircraft drift rate during off-course ground hover, Pilot 3

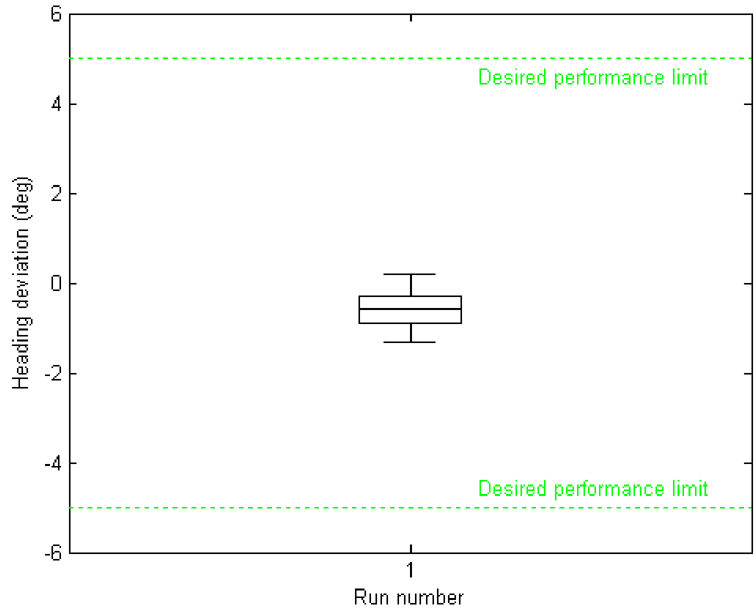

Figure 175 Maximum deviation of aircraft heading during off-course ground hover, Pilot 3

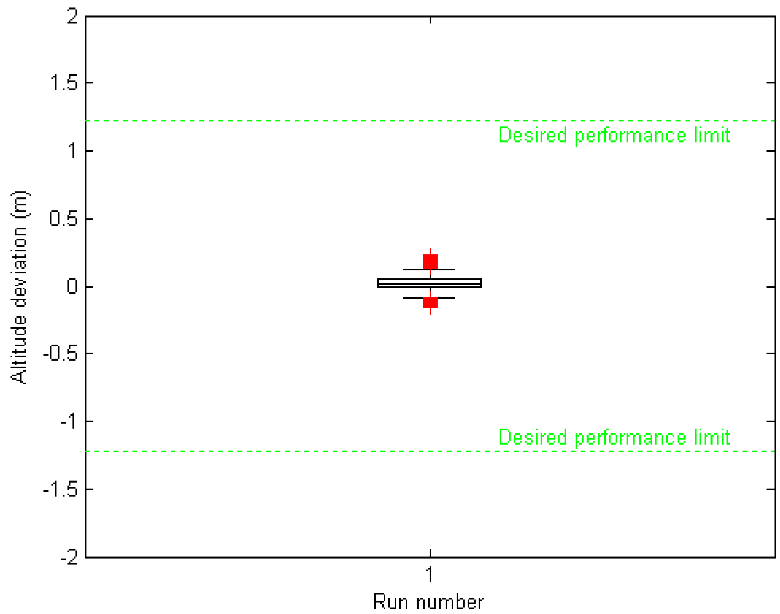

Figure 176 Maximum deviation of aircraft altitude during off-course ground hover, Pilot 3

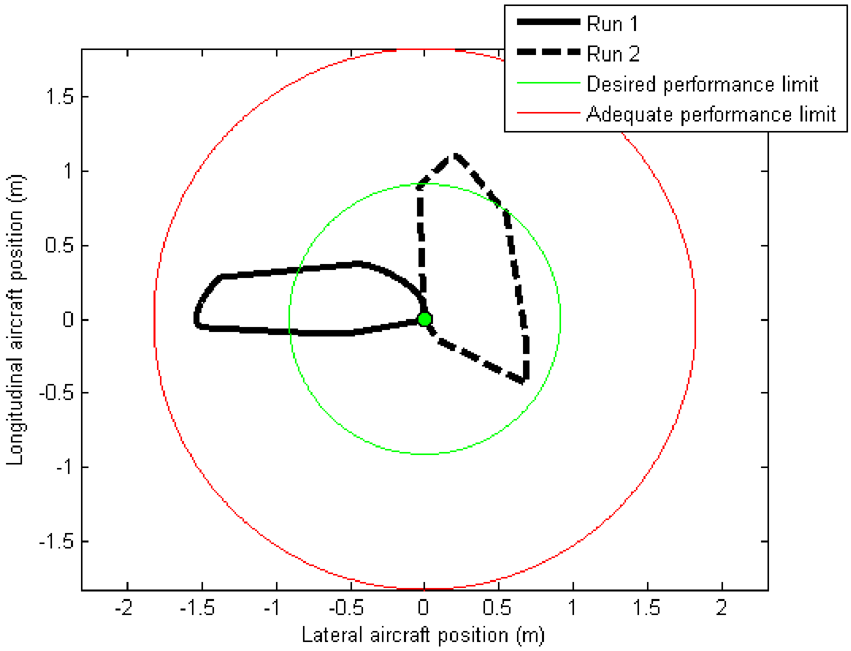

Figure 177 Maximum deviation of aircraft plan position during off-course ground hover, Pilot 4

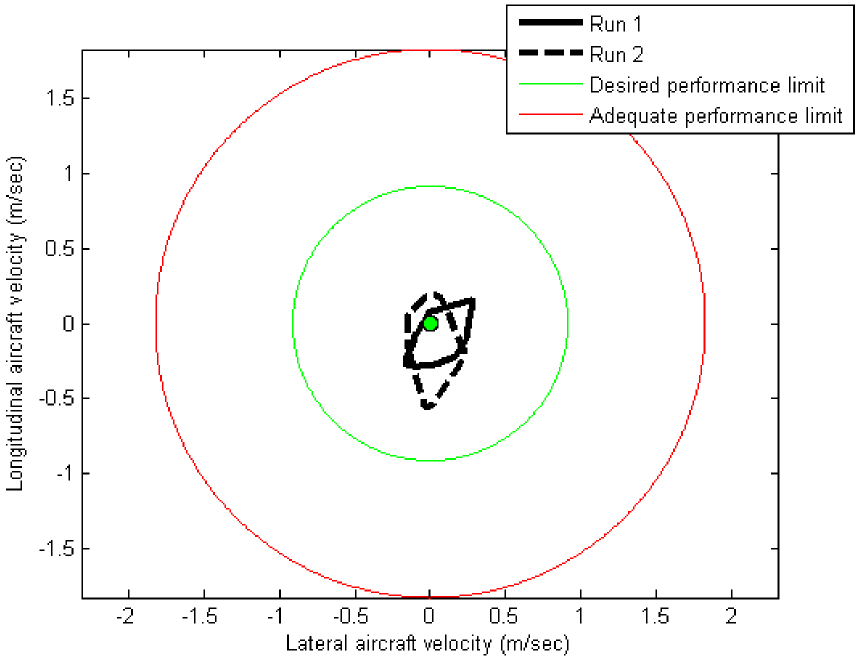

Figure 178 Maximum aircraft drift rate during off-course ground hover, Pilot 4

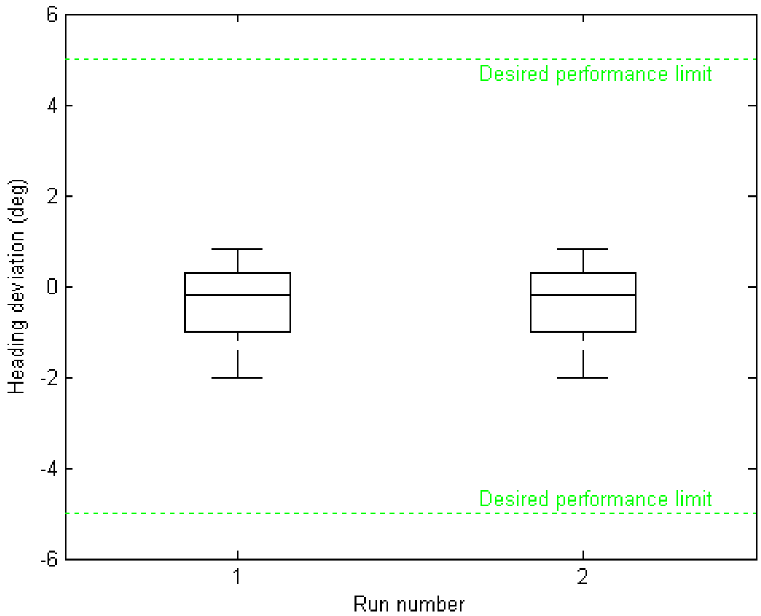

Figure 179 Maximum deviation of aircraft heading during off-course ground hover, Pilot 4

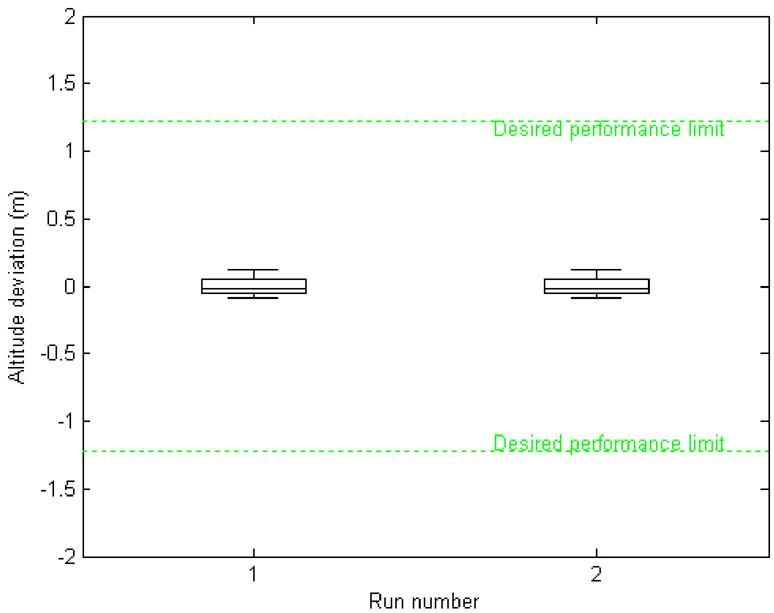

Figure 180 Maximum deviation of aircraft altitude during off-course ground hover, Pilot 4

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Helicopter performance, ADS-33, Maritime operations, Simulation, Handling qualities

19. ABSTRACT

This report describes the simulation experiment undertaken in the Air Operations Simulation Centre to assess the viability of a maritime hover manoeuvre in support of a Maritime Addendum to Aeronautical Design Standard 33.

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